Groundfish Stock Assessments for the West Coast of Canada in 1987 and Recommended Yield Options for 1988

J. Fargo, M. W. Saunders, and A. V. Tyler (Editors)

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Nanaimo, British Columbia V9R 5K6

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GROUNDFISH STOCK ASSESSMENTS FOR THE WEST COAST OF CANADA IN 1987 AND RECOMMENDED YIELD OPTIONS FOR 1988

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TABLE OF CONTENTS

Page

1. INTRODUCTION 1
2. LINGCOD 13
3, PACIFIC COD 45
4. FLATFISH 75
5. SABLEFISH 107
6. PACIFIC HAKE 126
7. DOGFISH 151
8. WALLEYE POLLOCK 159
9. SLOPE ROCKFISHES 166
10. SHELF ROCKFISH 227
11. INSHORE ROCKFISH 273
12. REFERENCES 295

ABSTRACT

Fargo, J., M. W. Saunders, and A. V. Tyler. 1988. Groundfish stock assessments for the west coast of Canada in 1987 and recommended yield options for 1988. Can. Tech. Rep. Fish. Aquat. Sci. No. 1617: 304 p.

Stock assessments and yield options are developed for the Pacific coast of Canada for the following species: lingcod, Pacific cod, petrale sole, Dover sole, rock sole, English sole, arrowtooth flounder, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, redstripe rockfish, silvergray rockfish, yellowtail rockfish, canary rockfish, quillback rockfish, copper rockfish, and yelloweye rockfish. The yield options are recommendations to the fishery managers of the Field Services Division on catch limitations and other fishery management procedures. Biological considerations only, rather than economic factors, are addressed in this document. The yield options are quantitative and are based on a series of appropriate mathematical methods, e.g. virtual population analysis, dynamic pool analysis, and Fournier stock-reconstruction procedures. Alternative options address the possibility of the fishery managers considering high risk and low risk yields in relation to a stock's future potential to produce. Other options, particularly for rockfish species, provide a selection of alternatives for managers to consider in regard to whether a stock should be re-built, maintained at status quo, or decreased through non-sustainable catches for present economic emergencies.

Key words: groundfish, stock assessment, fishery yields

RESUME

Fargo, J., M. W. Saunders, and A. V. Tyler. 1988. Groundfish stock assessments for the west coast of Canada in 1987 and recommended yield options for 1988. Can. Tech. Rep. Fish. Aquat. Sci. No. 1617: 304 p.

Les auteurs procèdent à des évaluations de stocks et élaborent des options de rendement pour les espèces suivantes de la côte canadienne du Pacifique : morue-lingue, morue du Pacifique, plie de Californie, sole à petite bouche, sole du Pacifique, sole anglaise, plie à grande bouche, morue charbonnière, merlu du Pacifique, aiguillat commun, morue du Pacifique occidental, sébaste du Pacifique, sébaste à bouche jaune, sébaste à oeil épineux, sébaste à raie rouge, sébaste argenté, sébaste à queue jaune, sébaste canari, sébaste à dos épineux, sébaste cuivré et sébaste aux yeux jaunes. Les options de rendement sont des recommandations faites aux gestionnaires des pêches de la Division des services sur le terrain concernant les limites de prises et d'autres procédures de gestion des pêches. Ce document traite seulement des questions d'ordre biologique plutôt que des facteurs économiques. Les options de rendement sont quantitatives et sont basées sur une série de méthodes mathématiques appropriées, par ex. l'analyse des populations virtuelles, l'analyse des stocks dynamiques, et les procédures de reconstitution des stocks par analyse de Fournier. Pour d'autres options, les auteurs examinent la possibilité que les gestionnaires des pêches envisagent des rendements à risque élevé et à risque faible en rapport avec la capacité future de production d'un stock. D'autres options, surtout pour les espèces de sébaste, offrent aux gestionnaires un choix de solutions de rechange à envisager pour savoir si un stock doit être reconstitué, maintenu dans son état actuel ou réduit au moyen de prises non soutenues, compte tenu des urgences économiques actuelles.

Mots-clés: poisson de fond, évaluation des stocks, rendements de pêche

1.0 INTRODUCTION

This document contains summaries of stock conditions of the important groundfish stocks, and recommendations for their management to the Offshore Division of the Fisheries Branch. This report is the more extensive report prepared every three years by the staff of the Groundfish Section of the Biological Sciences Branch, located at the Pacific Biological Station, Nanaimo, British Columbia, Canada, V9R 5K6.

Groundfish research staff began their assessments in the spring of the year using a multi-year data base for fishery statistics and biological research. A variety of assessment models were used including several sequential analysis models, age-independent surplus production models, yield-per-recruit, and linear models. Assessments were completed in August after review by a Committee of Department of Fisheries and Oceans (DFO) Groundfish scientists. Review may also incorporate outside investigators (government or non-government), where desired by the DFO Research Branch (FRB). Assessments are then reviewed by the DFO Pacific Stock Assessment Review Committee and recommended yield options are collated and sent to the Offshore Division of Fisheries Branch for consideration. Statistical summary areas are shown in Figure 1.1 and Figure 1.2. Summaries of yield options are given in Tables 1.1. Table 1.2 is a summary of the condition of stocks.

The assessments presented in this document represent the combined efforts of the Groundfish Section, including port samplers, data processors and the Ageing Laboratory. The individual assessments have generally been conducted and reported by the author(s) identified, however they may also have been modified as a result of subsequent reviews by other members of the Groundfish Section, or external reviewers appointed by the Pacific Stock Assessment Review Committee.

We present a number of levels of yield options. All may not be appropriate to apply to a particular species or stock. The seven yield options are: (i) zero yield; (ii) rebuilding harvest; (iii) sustainable; (iv) conservative-sustainable; (v) risk-sustainable; (vi) non-sustainable and (vii) unrestricted yield.

(i) Zero yield

This option could be entertained under situations of known and severe stock depletion, or where particular areas may represent necessary refuges for the fish. Additional ecological considerations might include situations where the subject stock acts as a predator on a less desirable species, and the objective is to maximize predation.

(ii) Rebuilding yield

Under this option the probability of overfishing is minimized while that of rehabilitating depleted stocks is increased. With the exception of option (i), this approach will incur the lowest risk of deleterious effects on stock biomass and dynamics. It is also true that it represents a lower yield than could be taken out of the stock on a sustainable basis. The most common application of this option is for stock rebuilding although for rockfish stocks this should be the approach to developing fisheries, because of the detection, response and corrective time frames (10-20 y) for rockfish species.

(iii) Sustainable yield

This option provides some opportunity to maintain stocks at existing levels. In many ways this is the least certain of the options available since it entrains many assumptions about the behaviour of stocks in response to fishing and biological processes. This option should be taken to mean that the probabilities of either decline or increase in yield (biomass) are approximately equal. The term "sustainable" should be understood in its broad sense, i.e. that the stock will oscillate around the expected level as a result of oscillation in recruitment, rather than be maintained at a fixed level. The amplitude and frequency of these oscillations may vary considerably among and within stocks at different levels of biomass. In the simplest terms, this is our best estimate of the highest yield at existing stock levels.

(iv) Conservative (low risk) -sustainable

Like the Sustainable Option this is an estimate of the tonnage that can be caught during the year and leave enough of the biomass for the stock to replenish itself through reproduction and body growth. However, data are often not as complete as should be for calculation of a single, firm estimate of the true value of the sustainable yield. When there is a high degree of uncertainty about the estimate, a cautious approach to setting the catch limits should be taken. The cautious or conservative estimate is often set simply as 50% or 75% of the calculated sustainable yield, depending on the biologist's understanding of the firmness of the estimate.

(v) (High) Risk-sustainable yield

This catch limit has some small chance of being a sustainable yield. The estimate is at the other end of the range from the Conservative-sustainable yield, and is above the Sustainable yield estimate. The level is often set simply as 25% or 50% higher than the sustainable yield value. Sometimes a central value for the sustainable yield is not given, only the Conservative and Risk levels. Risk levels should only be selected to provide relief from a specific case of economic hardship, and conscious recognition be made that decreases to sustainable levels in the near future might be the result of selecting this option.

(vi) Non-sustainable yield

While the sustainable option is derived from the biological properties of the species and stock composition, the non-sustainable level is largely an economic and management concept. The benefits of increased yield over the short term must be weighed against the lowered future yields resulting from overfishing. Employment of this option implies either experimental or non-biological management, since stock declines are highly probable with such a policy in effect over a significant part of the average life of a population cohort. This option might be considered when: socio/economic conditions require short-term yields in excess of sustainable harvest; experiments concerning well-defined and disparate exploitation rates are necessary; or, management policy requires sequential, pulsed fishing on several stocks.

This option requires that management will have to shift to a conservative policy to offset deleterious effects prior to major and irreversible stock changes. Thus, this option either guarantees a pulsed exploitation pattern if the stock is to be maintained at the most productive level, or accepts short-term gains over long-term productivity.

The hazard associated with this option will vary with the biological characters of the target stocks. In particular, the residence time of a cohort in the vulnerable stock will be a key determinant in the time for detection and response. Where residency is long, higher than sustainable yields may be maintained over several years in spite of strongly deleterious, yet undetected effects on subsequent cohorts. Conversely, a short residency may permit more rapid detection of adverse effects although incremental increases in quotas should be small if uncertainty about effects is high.

(vii) Unlimited yield

Few conditions would call for consideration of this option. Depletion of stocks and elimination of fisheries when harvests are uncontrolled are well documented throughout the world. However, this option might be considered: for experimental purposes; for stock eradication (in the case of competing species); or for economic returns where the loss of a particular stock does not outweigh the chaotic effects that lowered yield would create in the industry.

Table 1.1. Summary of yield options for west coast groundfish in 1988.

Area	Species	Management options
4B	Lingcod	1. Add time to winter fishing closure Nov. 15-Apr. 15. 2. Introduce minimum size limit of 58 cm for sport-caught lingcod to protect young.
3C	Lingcod	1. Sustainable: 1400 t quota. 2. Risk-sustainable: no quota, self regulation.
3D, 5A, 5B, 5C, 5D, 5E	Lingcod	No options proposed.
4B	Pacific cod	No options proposed.
3C/3D	Pacific cod	Close Amphitrite Bank Jan. 1-Mar. 31 and safety margin to all trawling.
5A/5B	Pacific cod	No options proposed.
5C/5D	Pacific cod	No quota proposed. Stock increasing rapidly.
5E	Pacific cod	No options proposed.
Coastwide	Petrale sole	1. Sustainable: trip limit 25,000 lb. 2. Risk-sustainable: No quota, self regulating.
4B	Flatfish	No options proposed.
3C/D	Flatfish	No options proposed.
5A	Rock sole	1. Sustainable: 100 t, 30,000 lb trip limit).

Table 1.1 (cont'd)

Area	Species	Management options
5B	Rock sole	1. Conservative-sustainable: 250 t, 30,000 lb trip limit. 2. Risk sustainable: 400 t, no trip limit.
5C	Rock sole	1. Conservative-sustainable: 100 t, 30,000 lb trip limit. 2. Risk-sustainable : 400 t, no trip limit.
5D	Rock sole	1. Conservative-sustainable: 100 t, 30,000 lb trip limit. 2. Risk-sustainable: 400 t, no trip limit.
5C/D	English sole	1. Conservative-sustainable: 400 t 2. Risk-sustainable: 600 t quota
	Arrowtooth flounder	1. Sustainable: 5,000 t.
5C/5D/5E	Dover sole	1. Conservative sustainable: 800 t quota, 2. Risk-sustainable: 1,000 t quota
Coastwide	Sablefish	1. Conservative-sustainable: 3500 t quota. 2. Risk-sustainable: 4500 t quota.
4B, not including MSA 19, 20	Pacific hake	1. Conservative-sustainable: 8,000 t quota. 2. Risk-sustainable: 16,000 t quota.
3C	Pacific hake	Yield options to be presented at a later date when all current biological information is collated in the joint Canada-U.S. assessment algorithm.

Table 1.1 (cont'd)

Area	Species	Management options
Coastwide (not including 4B)	Dogfish	1. Pulse fishing: variable annual quota until non-nuisance abundance reached. 2. Conservative-sustainable: 15,000 t. 3. Risk-sustainable: 25,000 t.
4B, not including MSA 12, 19, 20.	Dogfish	1. Pulse fishing: variable annual quota, see text. 2. Conservative-sustainable: 2,000 t annual quota. 3. Risk-sustainable: 3,000 t annual quota.
4B	Walleye	1. Conservative-sustainable: 2,500 t quota. 2. Risk-sustainable: 5,400 t quota.
3C/3D	Walleye pollock	Options not proposed.
5A/5B	Walleye pollock	Options not proposed.
5C/5D	Walleye pollock	Open fishing option proposed
5E	Walleye pollock	Options not proposed.
Coastwide	Yellowtail rockfish	Conservative-sustainable: 1,000 t. Risk-sustainable: 4,000 t.
3C	Silvergray rockfish	Conservative-sustainable: 25 t Risk-sustainable: 200 t
3D	Silvergray rockfish	Conservative-sustainable: 250 t Risk-sustainable: 350 t

Table 1.1 (cont'd)

Area	Species	Management options	
5A/5B	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	700 t 1,000 t
5C/5D	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	400 t 1,000 t
5E-S	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	100 t 250 t
5E-N	Silvergray rockfish	Conservative-sustainable: Risk-sustainable:	100 t 150 t
3C	Canary rockfish	Conservative-sustainable: Risk-sustainable:	200 t 400 t
3D	Canary rockfish	Conservative-sustainable: Risk-sustainable:	500 t 600 t
5A/5B	Canary rockfish	Conservative-sustainable: Risk-sustainable:	350 t 500 t
5C/5D	Canary rockfish	Conservative-sustainable: Risk-sustainable:	Unknown 500 t[a]
5E-N/S	Canary rockfish	Conservative-sustainable: Risk-sustainable:	Unknown 500 t[a]
3C	Pacific ocean perch	1. Rebuilding: 2. Conservative-sustainable: 3. Risk-sustainable:	0 t 100 t 200 t
3C	Redstripe rockfish	Conservative-sustainable: Risk-sustainable:	200 t 1,000 t
3D	Pacific ocean perch	Conservative-sustainable: Risk-sustainable:	200 t 600 t

Table 1.1 (cont'd)

Area	Species	Management options	
3D/5A	Yellowmouth	Conservative-sustainable:	250 t
		Risk-sustainable:	750 t
3D/5A	Redstripe	Conservative-sustainable:	350 t
		Risk-sustainable:	900 t
5A/5B	Pacific ocean perch	Conservative-rebuilding:	400 t
		Conservative-sustainable:	700 t
		Risk-sustainable:	1,000 t
5C/5D	Pacific ocean perch	Conservative-sustainable:	1,900 t
		Risk-sustainable:	3,000 t
5C/5D	Yellowmouth	Conservative-sustainable:	160 t
		Risk-sustainable:	500 t
5C/5D	Redstripe	Conservative-sustainable:	350 t
		Risk-sustainable:	570 t
5E-S	Pacific ocean perch	Conservative-sustainable:	400 t
		Sustainable:	700 t
5E-S	Yellowmouth	Conservative-sustainable:	400 t
		Risk-sustainable:	700 t
5E-S	Rougheye	Conservative-sustainable:	200 t
		Risk-sustainable:	300 t
5E-S	Grouped slope rockfish	January-June	
		Conservative-sustainable:	300 t
		Risk-sustainable:	600 t
		September-December	
		Conservative-sustainable:	600 t
		Risk-sustainable:	1,100 t
5E-S	Redstripe	Conservative-sustainable:	100 t
		Risk-sustainable:	200 t

Table 1.1 (cont'd)

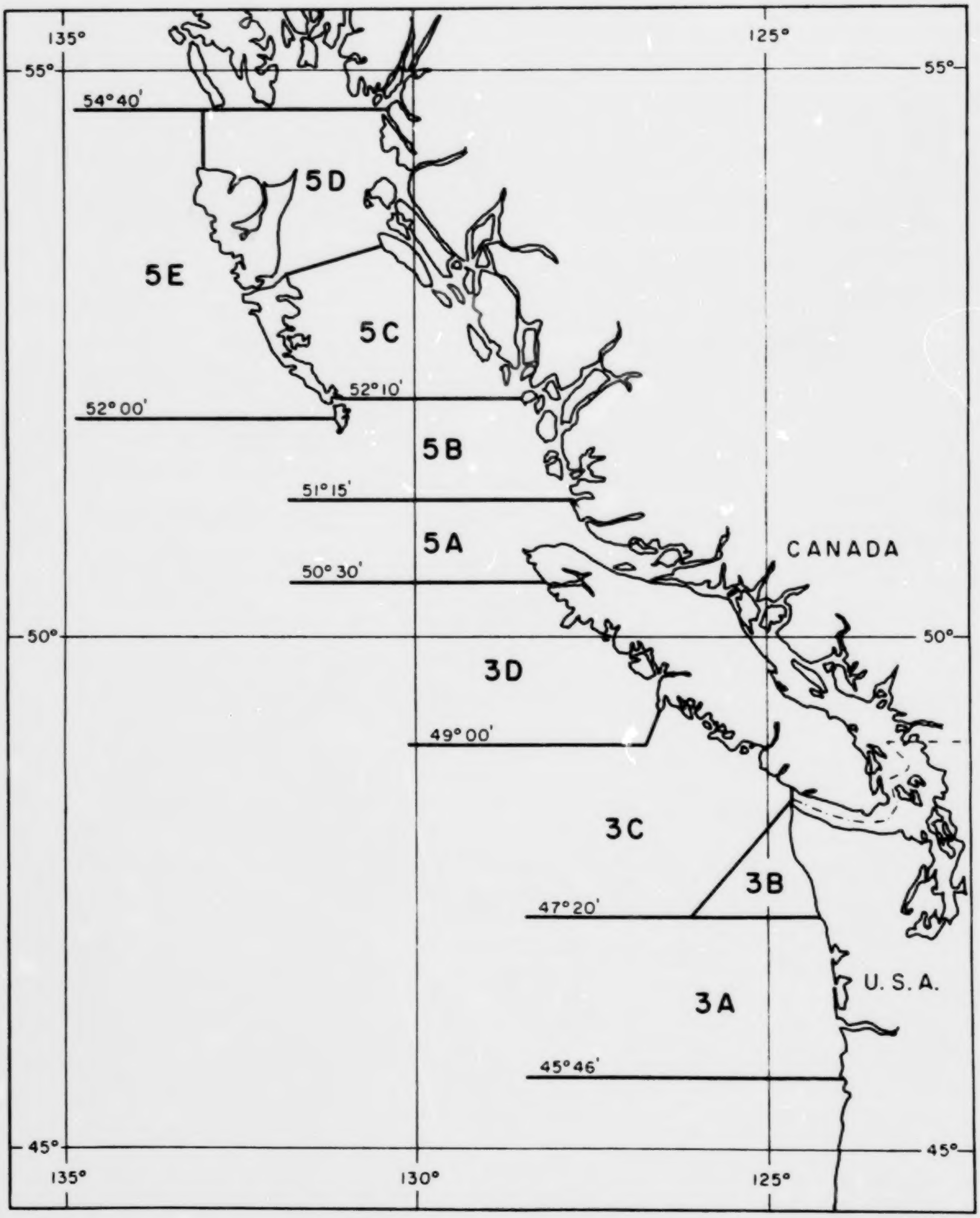
Area	Species	Management options	
5E-N	Pacific ocean perch	Conservative-sustainable: Risk-sustainable:	150 t 200 t
5E-N	Yellowmouth	Conservative-sustainable: Risk-sustainable:	350 t 500 t
5E-N	Rougheye	Conservative-sustainable: Risk-sustainable:	50 t 100 t
5E-N	Redstripe	Conservative-sustainable: Risk-sustainable:	500 t 700 t
4B-MSA-12	Copper/ Quillback	Conservative-sustainable: Risk-sustainable:	75 t 150 t
4B-MSA-13	Copper/ Quillback	Conservative-sustainable: Risk-sustainable:	50 t 100 t
4B-MSA-14-20, 28,29	Copper/ Quillback	Conservative-sustainable: Risk-sustainable:	150 t 200 t

[a] Recommended ceiling option for stocks with minimal landings history.

Table 1.2. Canadian views on current stock condition and abundance trends for groundfish species/species groups on the west coast of Canada.

Species or species group	TAC (1,000 t)	Current stock condition
Lingcod	1.4	average
Pacific ocean perch	0.00-3.00 (cons.-non sust.)[a]	low to average
Other rockfish	0.03-4.00 (cons.-non sust.)	average
Sablefish	4-5 (cons.-non sust.)	good
Pollock	2.5[b] (cons.)	average
Pacific cod	No TAC	average
Flatfish	c	average

[a] TAC range is from conservative to non-sustainable yield options.
[b] No TAC recommended for some areas.
[c] Three species managed by mixture of area quotas and trip limits.


135°
125°
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54°40'
5D
5E
5C
52°10'
52°00'
5B
51°15'
5A
50°30'
CANADA
50°
50°
3D
49°00'
3C
3B
47°20'
U. S. A.
3A
45°46'
45°
45°
135°
130°
125°

Fig. 1.1. International (Pacific Marine Fisheries Commission) Major Statistical Areas along the British Columbia coast.

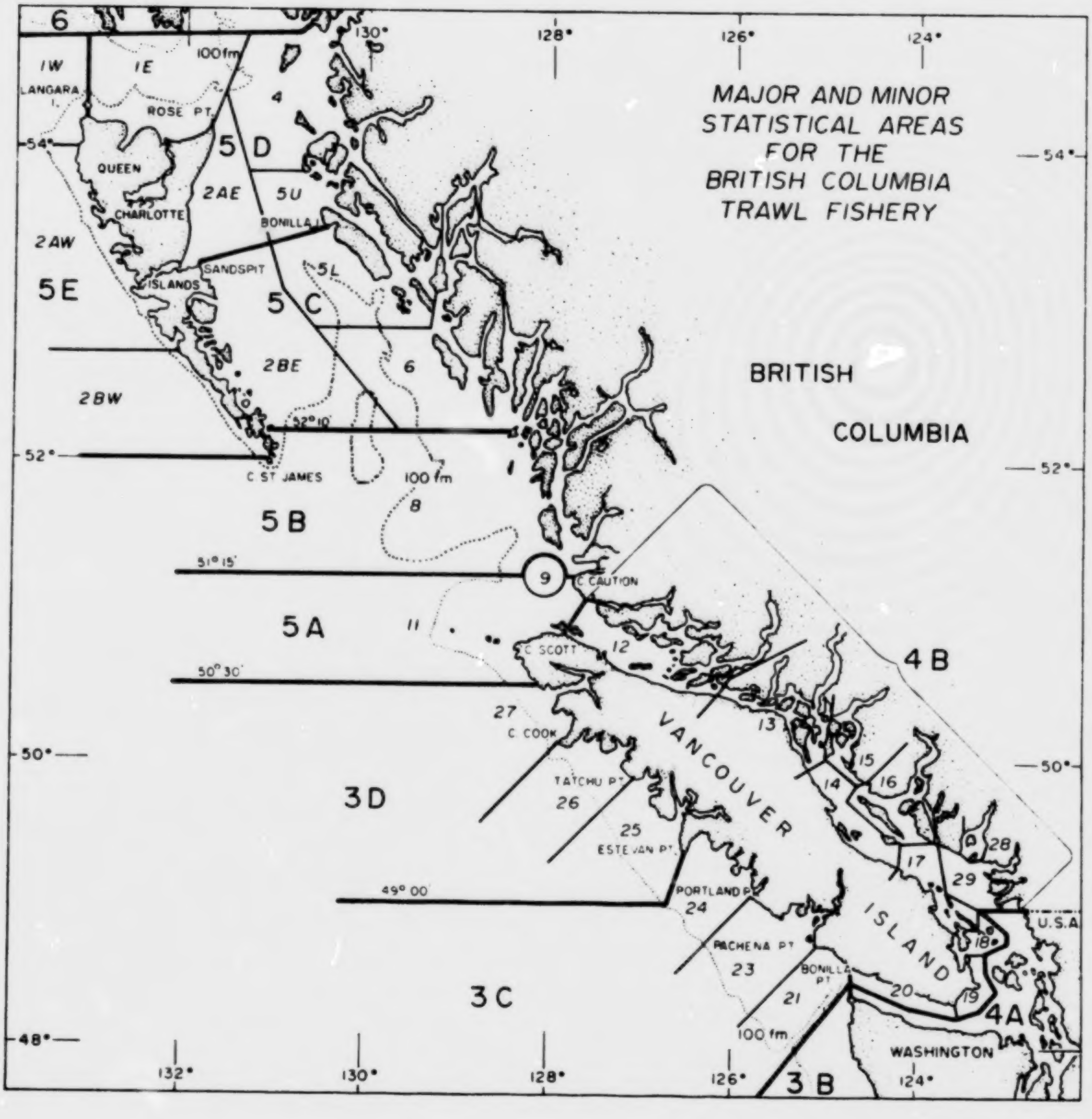
MAJOR AND MINOR
STATISTICAL AREAS
FOR THE
BRITISH COLUMBIA
TRAWL FISHERY
BRITISH
COLUMBIA
6
1W
1E
100fm
LANGARA I.
ROSE PT.
4
5D
QUEEN
CHARLOTTE
ISLANDS
2AE
5U
BONILLA
2AW
SANDSPIT
5L
5E
5C
2BE
6
2BW
52°10'
C ST JAMES
100 fm
8
5B
51°15'
9
C CAUTION
5A
11
C SCOTT
12
50°30'
4B
27
C COOK
VANCOUVER
ISLAND
13
14
15
16
TATCHU PT
26
3D
25
ESTEVAN PT
17
28
29
49° 00'
PORTLAND PT
24
U.S.A.
18
PACHENA PT
23
BONILLA PT
21
20
19
3C
4A
100 fm
WASHINGTON
3 B
130°
128°
126°
124°
132°
54°
52°
50°
48°

Fig. 1.2. International (Pacific Marine Fisheries Commission) Major and Minor Statistical Areas along the British Columbia coast.

2.0 LINGCOD

L. J. Richards and C. M. Hand

2.1 Coastwide

Yield options are not proposed on a coastwide basis.

2.2 Strait of Georgia and vicinity (Area 4B).

2.2.1 Introduction

The lingcod stocks in the Strait of Georgia have been exploited commercially since the early 1900s. The majority of commercial landings have been taken by handline-troll gear but comparatively minor catches have also been taken with trawl and longline gear. Recently, the sports rod and reel fishery has taken an increasing proportion of the total landings.

Tagging studies have shown that adult lingcod are very sedentary and remain close to their home reef after maturity (Chatwin 1956; Cass et al. 1983). Furthermore, the lingcod living in a particular reef area are probably the chief source of recruitment to that reef owing to their demersal nest building and guarding behaviour and to the limited dispersion of larvae after hatching (Cass et al., in prep.).

2.2.2 Landing statistics

The lingcod fishery began in the early 1900s and landings increased in magnitude to a peak of 3000 t in 1936 (Ketchen et al. 1983). Landings remained at relatively high levels until the early 1960s but have declined since that time. The present level is less than 200 t (Fig. 2.1). Lingcod landings taken by trawl and longline gear have not declined at the same rate as those taken by handline/troll gear (Table 2.1).

Fishing activity has been concentrated in the Campbell River area (MSA 13), the southern Gulf Islands area (MSA 17) and near Pender Harbour (MSA 16) (Table 2.2; Fig. 1.2). Since 1969, landings from the commercial fishery in MSA 16 have been less then 84 t.

Catch and effort statistics from sales slip data files have been available from the Department of Fisheries and Oceans, Statistics Division, since 1967. Historically, the bulk of handline effort has been directed at lingcod, but increasing amounts have been re-directed at rockfish in nearshore areas since the late 1970s. To avoid including effort directed at rockfish in this analysis, only data records meeting a specified qualification criterion were used to compute landings per unit effort (LPUE). Several different qualification criteria were used, including minimum daily landings, minimum days fished per season, minimum seasonal landings and various combinations of these. Similar trends in LPUE were obtained regardless of the qualification criterion used, so for convenience, a minimum daily landing of 100 kg was specified for subsequent analysis. An index of total annual effort ("equivalent effort") was defined as the ratio of total landed catch to qualified LPUE.

LPUE by statistical area and equivalent effort from 1967 to 1986 are summarized in Table 2.3. Landed catch, LPUE and equivalent effort for MSA 13 and 17 are shown in Figures 2.2 and 2.3. The LPUE index, combined over all areas, has averaged 170 kg/boat-day from 1967 to 1979 but declined gradually to a low of 74 kg/boat-day in 1986. Landings and equivalent effort have also fluctuated, but overall, exhibit a declining trend. The proportion of total landings meeting the qualification level remained more or less constant until 1984 but dropped by 28% between 1984 and 1986. This indicates that a greater proportion of the lingcod catch was taken incidentally to other handline fisheries, such as those for nearshore rockfish.

In the Campbell River area (MSA 13), LPUE averaged 260 kg/boat-day from 1967 to 1976 and declined thereafter to the 1986 low of 53 kg/boat-day. The high LPUEs between 1971-76 were associated with unusually low effort. LPUEs in recent years, however, are low despite reduced fishing effort (Fig. 2.2).

In MSA 17, LPUE remained fairly stable at an average of 150 kg/boat-day from 1967 to 1978 even though effort declined during this period. Landings and effort have since declined steadily and LPUE has decreased slightly (Fig. 2.3).

The number of vessels reporting qualified landings has decreased from 253 in 1979, the first year for which information on individual vessels was available, to 83 in 1986 (Table 2.4). The number of vessels entering the fishery each year has also decreased. An average of 78% of vessels dropped out of the fishery after their first year of fishing between 1979 and 1986. Thereafter, however, their residency in the fishery was relatively high.

The sports hook and line fishery has been monitored since 1980 by creel and overflight surveys (Shardlow and Hoyt, unpublished data). These surveys provide estimates of the numbers of lingcod caught but no estimates of fishing effort. Sport landings have averaged 125 t/year between 1980 and 1986 except 1984 when an estimated 220 t were landed (Table 2.5.). A comparison of sports landings and handline commercial landings shows that the sports catch has exceeded the commercial catch since 1984. The sports fishery is taking an increasing proportion of the total lingcod catch each year.

Lingcod are also the target of an underwater spear fishery. A survey of the diving community in the Strait of Georgia was undertaken in the fall of 1983 which provided estimates of diving effort and the relative importance of various activities, including spearfishing (McElderry and Richards 1984). An estimated 50% of divers surveyed made dives for the purpose of spearfishing. The number of lingcod taken was very roughly but conservatively estimated at 80 t for 1983, or approximately 65% of the average annual sport catch.

2.2.3. Condition of the stock

Lingcod stocks in the Strait of Georgia appear to be in poor condition, especially in statistical areas 13 and 17. Landings, effort and LPUE have declined steadily over the past five years. Fewer vessels are participating in the lingcod fishery than ever before, and an increasing proportion of total landings are taken incidentally to other fisheries, primarily those for rockfish.

Overfishing is suspected as the cause of the decline in abundance for the following reasons: First, size frequency data from commercial samples in statistical areas 13 and 17 indicate that the mean length of both male and female lingcod has decreased, particularly between 1982 and 1984 (Figs. 2.4a and 2.4b). This decrease in average size cannot be attributed to strong recruitment of small fish because landings and LPUE have declined concurrently. Second, the sport fishery has taken an increasing proportion of the total landings in recent years, and these catches generally comprise smaller lingcod than those of the commercial fishery (Fig. 2.4c). In fact, an estimated 80% of male and 68% of female lingcod caught in the sports fishery from 1983 to 1986 were less than 60 cm fork length, and most of these would have been immature (Hand and Richards, in prep.). However, the average size of lingcod taken in the sports fishery has remained fairly constant over this period.

Examination of historical landings shows that even after a long period of exploitation, landings and effort were relatively stable in statistical areas 13 and 17 through the 1970s, and only dropped to extremely low levels in the past 4 or 5 years. It is not known why lingcod stocks in the Strait of Georgia can no longer support the magnitude of fishery that was sustained historically. Poor recruitment associated with unprecedented low spawning stocks may be responsible; alternatively, changes in climate or predator populations could be involved. In any case, the stocks appear to be declining in all areas under current levels of exploitation by the fishery.

In an attempt to rebuild stocks, the existing fishing closure (December 31-March 31) was extended in 1979 (November 15-April 14) to further protect the pre-spawning aggregation, protect the guarding males and improve recruitment. As stocks have apparently continued to decline since that time, the extended winter closure is, in itself, an insufficient means of controlling overfishing.

2.2.4 Yield options

The preceding analysis suggests that current yield levels cannot be sustained, especially in statistical areas 13 and 17. Two management strategies are suggested to reduce yield and protect lingcod at vulnerable stages in their life history.

1) Minor statistical area closures should help to rebuild local stocks because mature lingcod are sedentary and fish nesting on a particular reef system are probably the chief source of recruitment to that reef. Minor statistical areas that have been heavily exploited, for example MSA 13 and MSA 17, could be closed to both commercial and sports fishing either entirely or for a portion of the fishing season only. Lingcod landings for the first three months of the fishery (April-June) account for approximately 20% each of the annual catch while the remaining 40% is landed fairly evenly over the last five months of the fishery. Closing areas for any of these periods should result in a comparable reduction of landings and effort.

2) A size limit on the sports fishery may also be prudent in order to reduce overall effort in this fishery. At present, there is no strong evidence to indicate that landings of immature lingcod adversely affect spawning stocks. However, it should be noted that lingcod stocks have apparently declined during the same period that the sports fishery was taking an increasing portion of the total catch and that over 60% of female lingcod taken in the sports fishery are immature. A size limit on the sports fishery would increase the number of fish surviving to maturity, provided fish released after capture survive. The impact of a minimum size limit cannot be assessed without effort data from the sports fishery. However, studies in Puget Sound have shown that imposing a minimum size limit of 26 inches (66 cm) would result in a 56% increase in the catch of large (greater than 30 lb.) lingcod at 1983 fishing levels (Bargmann 1983). Yield-per-recruit calculations for lingcod fished off the west coast of Vancouver Island, which grow at similar rates to the Strait of Georgia lingcod (Cass et al. in prep.), suggest that the greatest increase in yield occurs between the ages of 4 to 6 years (Cass 1985) or at lengths of approximately 60 to 70 cm. Of course, it should be recognized that total landed weight may be less important to sports fishermen than the number of fish landed. However, surveys of anglers in Puget Sound have indicated that the majority favor a minimum size limit intended to increase the chance of catching a trophy fish (Bargmann 1983). At present, a size limit of 58 cm is in effect for the commercial fishery. It is suggested that the same size limit be imposed on the sport fishery.

2.3 West Coast Vancouver Island

2.3.1 Introduction

Lingcod off the west coast of Vancouver Island are assumed to exist as two discrete stocks or groups of stocks, one off southwest Vancouver Island (Area 3C), and one off northwest Vancouver Island (Area 3D). Analyses and lingcod landing statistics are presented by major statistical area. A comprehensive analysis of the population dynamics of lingcod in Area 3C, using a size-structured model (Schnute 1987), is in preparation. Preliminary results from this analysis form the basis for the Area 3C recommendations, and by extension, for the Area 3D recommendations.

2.3.2 The fishery

Lingcod stocks off southwest Vancouver Island are exploited by trawl and by hook and line fisheries. There have also been undocumented, and presumably small, landings by Indian food fisheries, recreational fisheries and foreign national (other than United States) fisheries. The hook and line fishery includes a targeted longline fishery and incidental landings by salmon troll vessels. The commercial trawl fishery accounts for the majority of the lingcod landings. Prior to 1987, there were no legal restrictions on the lingcod landings, except for occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit, in 1942. Lingcod landings were limited in the past by low market demand. In 1987, a 1400 t quota was placed on Area 3C lingcod landings.

2.3.3 Landing statistics

The compilation of landing statistics for Area 3C is discussed in detail in Cass et al. (in prep.), and differs from previous assessments (Cass 1985). Briefly, LPUE is calculated from interviewed trawl landings between May-September. A landing was included only if lingcod accounted for at least 25% of the total landing weight, and the vessel used double gear. The effort recorded on the landing was standardized for vessel horsepower class (Westrheim and Foucher 1985b; Table 8). In addition, the proportion of the landings that could be accounted for by lingcod above a defined weight of 2.25 kg was determined annually from biological samples of the landings. The defined weight was chosen to represent "V", weight at recruitment (Schnute 1987). LPUE is the ratio of the sum of the qualified landings to the sum of the qualified efforts, corrected by the proportion of fish of weight V or greater. Effort was the ratio of total all-gear landings to the corresponding LPUE.

Lingcod landings from Area 3C have generally varied between 700-2000 t (Table 2.6; Fig. 2.5). The lowest recorded landing was 451 t in 1978 and the highest was 3623 t in 1985. Line landings (combined handline/troll and longline) have tended to be less variable than trawl landings and have averaged 187 t between 1956-86. The 1986 total landing was below average at 1077 t. A significant increase in the 1986 line landings did not occur as projected, although the 1986 line landings were above average at 241 t. Similarly, the decrease in LPUE projected in 1986 (Cass 1987) did not materialize, and LPUE in 1986 was 325 kg/h, just below the historical average of 332 kg/h.

The compilation of landing statistics for Area 3D was similar to that discussed for Area 3C. In years for which there were no Area 3D commercial lingcod samples, the proportion of fish of weight "V" or greater in the landings was estimated from the Area 3C samples. LPUE calculated by this method from qualified trawl landings is a less useful abundance index for Area 3D than for Area 3C, because line landings account for a higher proportion of the total Area 3D landings. For example, only 10% of the total landings met the qualification requirements in 1985 and in 1986.

Lingcod landings from Area 3D have ranged from 166 t in 1959 to 984 t in 1968 (Table 2.7; Fig. 2.6). Landings in 1986 were 473 t, just above the historical average of 401 t. Although the LPUE of 306 kg/h in 1986 was 33% lower than in 1985, it was greater than LPUE between 1980-84.

2.3.4 General biological information

Biological samples from the commercial trawl fishery for Area 3C lingcod have been collected annually since 1956. The samples provide information on the length distribution and, beginning in 1977, the sex and age composition of lingcod in catches from known locations, depths of fishing and dates. The fin-ray method of ageing (Beamish and Chilton 1977) as applied to Area 3C lingcod has been partially validated through tagging studies of oxytetracycline-injected fish (Cass and Beamish 1983).

Because landings are recorded by weight, all length measurements were converted into weight for consistency in the analysis. All analyses of commercial samples are based on collections between May-September only. Fork length FL (cm), dressed length DL (cm), and weight WT (kg) are related by the following rules:

$FL=-1.8+1.258*DL$ (Wendler 1953)

$WT= 3.488E^{-6}*FL^{3.246}$ (derived from data in Cass et al. 1986).

Female lingcod have a faster growth rate than male lingcod. However, as the purpose was to define the growth of a typical exploited population, samples from male and female lingcod were combined in proportion to their frequency in the landings. Sex was not identified in the biological samples collected prior to 1977. Annual weight-frequency distributions from Areas 3C and 3D are shown in the form of tabular histograms in Tables 2.8 and 2.9, respectively. Growth parameters for Area 3C were estimated from the age-weight relationship using equation 1.14 of Schnute (1985). Tag-recapture data were also available for Area 3C (Cass et al. 1983). Additional estimates of growth parameters were obtained from the regression of 1983 recapture weight against 1982 release weight. These estimates were similar to the age-weight estimates.

By the model of Schnute (1987, equation (1.3)), a fish at recruitment weight "V" grows to weight

$$V'=W+\rho*V$$

in one year, where in the usual von Bertalanffy form,

$$W=W_\infty(1-e^{-k}) \text{ and } \rho=e^{-k}.$$

For Area 3C lingcod, a "V" of 2.25 kg was chosen by visual inspection from the 1956-86 average weight-frequency distribution (Fig. 2.7). This was the smallest weight at which a significant portion of the catch occurred. Estimates of the remaining growth parameters were $V'=2.91$, $W=0.693179$ and $\rho=0.985254$.

Lingcod in Area 3C recruit to the fishery over ages 2-6 (Table 2.10). Although trends in age frequency are somewhat difficult to interpret, the high apparent abundance of lingcod in the mid-1980s could have resulted from a series of strong year-classes in the late 1970s.

2.3.5 Condition of the stock

The model of Schnute (1987, equation 3.27) can be used to determine the effect of the fishery on the condition of lingcod stocks. Application of the model involves estimation of two main parameters, survival from natural mortality, σ, and catchability, q, from the LPUE and weight frequency time series. For comparison, σ and q were estimated from a simple model of the annual loss of tagged fish, due to natural mortality and fishing, following releases of tagged fish in Area 3C in 1982. Based on the LPUE data from Area 3C, the 95% confidence interval for σ and q ranged between 0.65-0.97 for σ, as q ranged between 0-0.05 per 1000 trawl-h. The maximum value of q represents an exploitation rate in 1985 and 1986 of 0.39 and 0.17, respectively. Based on the tagging data, the 95% confidence interval for σ and q ranged between 0.34-0.59 for σ, as q ranged between 0.06-0.09 per 1000 trawl-h.

The two models resulted in parameter sets with non-overlapping ranges for Area 3C. The LPUE data suggest that the present fishery is having little or no effect on the stock. The tagging data demonstrate that the exploitation rate is high. If tag loss or non-reporting of tags is considered, then the tagging model exploitation rate would be even higher. The only apparent, consistent explanation for these results is that the stock is maintained by immigration from non-trawlable areas. If the LPUE model is modified to allow for a constant immigration term, then the 95% confidence interval for σ is 0.3-0.5, a range more consistent with the tagging data.

There were no tagging data from Area 3D to compare with LPUE data. Based on the LPUE data, the 95% confidence interval for σ and q ranged between 0.62-0.94 for σ, as q ranged between 0-0.18 per 1000 trawl-h. The maximum value of q represents an exploitation rate in 1985 and 1986 of 0.22 and 0.26, respectively. These rates are similar to those for Area 3C.

The LPUE and tagging model analysis is still incomplete. We tentatively conclude that Area 3C and Area 3D lingcod stocks are sustaining current levels of exploitation by the trawl and line fleets, because the stocks are maintained by immigration from unexploited areas. However, if the line fleet expands into new areas, there could be detrimental effects on the Area 3C and 3D stocks.

2.3.6 Yield options

Pending completion of the Area 3C lingcod analysis, the following yield options are proposed:

conservative-sustainable - 1400 t
risk-sustainable - no quota

Yield options are not proposed for Area 3D.

2.4. Queen Charlotte Sound

2.4.1 Introduction

Commercially exploited lingcod stocks are located on the Cape Scott (Area 5A) and Goose Island (Area 5B) grounds. Few commercial samples are available for Area 5A lingcod, and because landing trends are similar in both areas, lingcod in Queen Charlotte Sound are treated as one stock for this assessment.

2.4.2 The fishery

Lingcod stocks in Queen Charlotte Sound are primarily exploited by commercial trawl vessels. There are also small landings by hook and line vessels. Lingcod have generally been a relatively minor component of the Queen Charlotte Sound trawl fishery.

2.4.3 Landing statistics

The compilation of landing statistics for Area 5A/B was similar to that discussed for Area 3C (section 2.3.3). LPUE for Area 5A and 5B was calculated from 25% qualified interviewed trawl landings between May-September. Effort was standardized for vessel horsepower class (Westrheim and Foucher 1985b; Table 8). LPUE for Area 5A/5B combined was also corrected for a weight at recruitment to the fishery of 2.25 kg, based on the average weight-frequency distribution of the 1956-86 commercial samples (Fig. 2.8). Effort was calculated from the ratio of total landings to LPUE.

Landings from Area 5A and Area 5B contributed about equally to the Area 5A/B total between 1956-70 (Table 2.11; Fig. 2.9). For every year since 1970, landings have been greater from Area 5B. However, the trends in landings and LPUE have remained similar in the two areas. The 1986 combined landing of 1700 t and the corresponding LPUE of 366 kg/h were the highest recorded since the 1966-68 fishery.

2.4.4 General biological information

Biological samples from the commercial trawl fishery for Area 5A/B lingcod have been collected almost annually since 1956. The samples provide information on the length distribution, and beginning in 1977, the age and sex composition of lingcod in the commercial landings. The analysis is based on samples collected between May-September only, with data from male and female lingcod combined. The 1979 sample was excluded from the analysis as the sample was comprised almost entirely of female lingcod. The proportion of male lingcod varied between 0.25 and 0.54 for other years for which information on sex was available.

Based on data described in Cass et al. (1986), weight WT (kg) can be estimated from fork length FL (cm) by the relationship

$$WT = 1.050E^{-5} * FL^{2.991}.$$

Annual weight-frequency distributions of lingcod from the commercial samples are shown in the form of tabular histograms in Table 2.12, with the average distribution in Fig. 2.8.

No tagging data were available for Area 5A/B, and growth parameters were estimated from the age-weight relationship. From equation (1.3) of Schnute (1987), the estimates were $V'=2.6086$, $W=0.441219$ and $\rho=0.963281$ with $V=2.25$. Lingcod in Area 5A/B have a slower growth rate than in Area 3C.

Only a few years of age-frequency data are available for Area 5A/B (Table 2.13). It appears that a few strong year-classes occurred in the late 1970s and appeared as peaks in the weight-frequency distribution between 1980-83. As peaks in the weight-frequency distribution also occurred at small weights in 1985-86 (Table 2.12), the high abundance in 1986 probably resulted from a strong 1982 year-class entering the fishery.

2.4.5 Condition of the stock

Survival from natural mortality, ρ, and catchability, q, were estimated from equation (3.27) of Schnute (1987). The 95% confidence interval for ρ and q ranged between 0.81-1.0 for ρ, as q ranged between 0-0.05 per 1000 trawl-h. The maximum value of q represents an exploitation rate in 1985 and 1986 of 0.19 and 0.22, respectively. Based on the Area 3C analysis, we conclude that stocks are sustainable at these rates of exploitation. Lingcod stocks in Area 5A/B appear to be at above-average levels of abundance.

2.4.6 Yield options

Yield options are not proposed for this area.

Table 2.1. Commercial handline-troll, longline and trawl landings of lingcod (t) from the Strait of Georgia and vicinity (Area 4B), 1951 - 86.

Year	Handline/troll[a]	Longline	Trawl	Total
1951	1279.5	27.4	48.1	1355.0
1952	1488.8	17.2	54.0	1560.0
1953	1179.2	6.3	28.1	1213.6
1954	1449.4	9.4	68.0	1526.8
1955	1220.1	8.5	50.6	1279.2
1956	1512.1	9.6	55.7	1577.4
1957	1539.7	4.5	42.0	1586.2
1958	1445.6	4.0	74.6	1524.2
1959	1183.0	6.7	336.4	1526.1
1960	1250.6	21.4	184.1	1456.1
1961	1157.7	30.7	102.1	1290.5
1962	1272.8	14.3	75.4	1362.6
1963	989.3	9.3	39.6	1038.2
1964	870.4	5.5	90.3	966.2
1965	779.7	6.5	93.8	880.0
1966	771.3	20.0	53.7	845.0
1967	781.0	14.5	54.4	849.9
1968	729.8	12.5	94.6	836.9
1969	747.9	19.9	51.6	819.4
1970	792.0	31.3	48.8	872.1
1971	564.9	34.3	60.5	659.7
1972	513.4	10.3	34.5	558.2
1973	373.1	31.2	15.0	419.3
1974	354.7	16.2	47.6	418.5
1975	331.4	37.3	33.9	402.6
1976	316.0	15.3	43.6	374.9
1977	408.7	24.9	32.1	465.7
1978	445.2	56.5	42.6	544.3
1979	505.5	56.0	23.8	585.3
1980	342.1	12.0	26.1	380.2
1981	334.5	9.2	66.4	410.1
1982	358.8	11.4	196.6	566.8
1983	274.7	12.6	135.4	422.7
1984	182.7	10.4	90.6	283.7
1985	129.2	8.6	34.0	171.8
1986	99.1	16.1	44.4	159.6

[a] Source: British Columbia catch statistics. Department of Fisheries and Oceans.

Table 2.2. Commercial handline-troll landings of lingcod (t) from the Strait of Georgia and vicinity (Area 4B) by minor statistical area, 1951-86.[a]

Year	Minor Area											
	12	13	14	15	16	17	18	19	20	28	29	Total
1951	9.3	397.3	79.8	39.3	95.4	357.2	253.2	30.0	17.2	1.7	0.3	1279.5
1952	7.2	426.1	83.5	72.9	167.3	435.6	235.5	28.6	25.2	7.0	0.0	1488.8
1953	3.3	345.8	84.3	44.8	162.3	288.2	179.0	38.9	28.1	4.4	0.1	1179.2
1954	5.6	437.3	157.6	21.5	243.1	361.7	169.1	33.7	13.2	4.8	1.8	1449.4
1955	2.2	329.9	84.4	58.8	241.6	338.8	112.3	44.1	8.0	0.0	0.0	1220.1
1956	3.9	564.7	96.3	60.6	235.0	396.8	106.9	44.1	2.1	1.2	0.6	1512.1
1957	4.9	542.4	82.4	107.1	286.0	362.6	96.9	54.0	2.3	0.3	0.8	1539.7
1958	11.2	497.2	105.6	79.3	229.7	350.2	93.5	73.7	4.5	0.6	0.0	1445.6
1959	10.8	338.3	85.6	31.2	166.8	343.7	85.3	104.5	0.8	0.6	15.4	1183.0
1960	18.7	336.9	110.7	47.1	157.3	372.2	97.0	82.8	23.1	1.3	3.5	1250.6
1961	24.5	393.1	91.4	45.6	170.6	268.4	64.0	63.3	29.2	5.1	2.4	1157.7
1962	151.0	407.5	111.2	60.4	138.1	240.9	57.2	75.8	19.1	7.8	4.1	1272.9
1963	59.5	301.4	63.1	29.4	158.7	248.3	44.7	63.5	20.5	0.1	0.1	989.3
1964	31.9	288.8	43.3	18.7	168.6	191.5	53.8	52.6	20.7	0.1	0.4	870.4
1965	26.5	303.2	52.0	6.6	133.8	153.4	50.0	39.3	10.5	0.0	4.6	779.7
1966	36.6	298.7	61.7	21.7	117.1	125.2	61.2	33.0	16.1	0.0	0.0	771.3
1967	43.6	332.8	55.7	19.8	128.7	105.9	69.9	17.8	6.4	0.0	0.4	781.0
1968	43.6	273.5	53.5	22.0	102.0	155.9	53.3	14.8	10.5	0.0	0.7	729.8
1969	55.3	227.7	72.1	55.9	108.2	141.5	52.3	31.6	3.2	0.0	0.1	747.9
1970	38.0	220.5	38.0	80.9	83.6	266.3	35.3	23.4	5.4	0.0	0.6	792.0
1971	31.7	119.2	28.6	66.5	77.2	197.8	22.7	18.8	2.2	0.1	0.1	564.9
1972	27.5	152.0	23.2	42.9	76.5	129.8	19.6	38.1	2.4	0.0	0.5	513.4
1973	8.4	85.9	8.4	57.6	28.2	121.2	34.4	27.1	1.1	0.6	0.2	373.1
1974	9.3	129.6	13.3	22.7	16.4	124.5	22.2	14.8	1.6	0.0	0.3	354.7
1975	5.5	93.9	9.5	68.5	11.5	118.0	10.9	8.3	4.4	0.0	0.9	331.4
1976	7.9	96.0	12.9	70.5	16.6	81.9	13.4	7.3	5.9	3.2	0.4	316.0
1977	18.2	128.0	31.4	54.0	18.4	98.5	40.6	15.1	2.6	1.6	0.3	408.7
1978	12.4	152.4	19.7	33.0	5.9	138.4	36.1	40.8	4.3	0.2	2.0	445.2
1979	18.1	212.7	32.6	28.7	11.4	131.0	25.5	28.8	12.3	4.3	0.1	505.5
1980	13.3	128.8	12.8	25.8	6.6	103.0	21.1	23.0	5.3	1.7	0.7	342.1
1981	15.6	136.8	20.8	34.6	10.1	83.0	13.6	16.3	3.2	0.0	0.5	334.5
1982	16.5	177.4	14.4	45.4	7.7	59.2	19.0	15.6	2.1	0.4	1.1	358.8
1983	15.0	112.0	17.8	32.9	6.8	54.8	16.4	14.0	4.4	0.3	0.3	274.7
1984	14.6	65.5	7.0	4.0	5.2	42.2	28.8	12.7	2.5	0.0	0.2	182.7
1985	17.2	46.0	8.2	3.9	0.2	26.1	15.2	9.9	2.2	0.0	0.3	129.2
1986	16.2	20.0	11.4	0.07	0.5	14.4	12.6	13.5	1.2	0.0	0.3	99.1

[a] Source: 1951-1966 British Columbia catch statistics, Department of Fisheries and Oceans, Annual Reports. 1967-1986: Sales slip data files.

Table 2.3. Qualified LPUE (kg/boat-day) by MSA, LPUE combined over all areas, total lingcod landings (t) by handline-troll and longline, the proportion of the total catch by these gears that satisfies the qualification criterion, and equivalent effort (boat-days) as calculated from the ratio of total line landings to the combined LPUE.

	MSA										LPUE	Landings		Effort
Year	12	13	14	15	16	17	18	19	20	28/29	(kg/day)	(tonnes)	Prop.	(boat-days)
1967	58	301	236	314	213	127	124	164	130	87	181.1	795.5	0.86	4313
1968	37	318	179	375	194	127	110	168	157	227	156.8	742.3	0.89	4734
1969	57	272	168	438	213	136	129	292	128	-	170.3	767.8	0.89	4509
1970	50	254	168	351	196	175	154	228	161	257	182.0	823.3	0.90	4524
1971	83	266	171	267	196	166	113	217	275	25	174.2	599.2	0.89	3440
1972	50	301	201	283	178	143	150	191	245	147	164.9	523.7	0.85	3176
1974	36	312	253	269	135	139	135	170	156	327	172.1	370.9	0.90	2155
1975	23	312	160	242	194	171	189	193	208	46	189.5	368.7	0.94	1966
1976	38	275	150	250	123	174	126	128	168	140	181.2	331.3	0.89	1825
1977	52	200	192	256	222	148	125	136	45	115	155.9	433.6	0.76	2781
1978	74	192	126	206	278	155	105	131	33	210	150.8	501.8	0.88	3327
1979	76	198	144	270	184	224	116	124	144	163	173.8	561.5	0.85	3231
1980	73	274	87	220	92	167	95	101	105	119	159.7	354.1	0.85	2217
1981	168	177	90	194	129	148	87	94	77	46	146.1	343.7	0.87	2352
1982	66	189	85	152	83	129	130	96	100	55	139.8	370.2	0.86	2648
1983	123	138	118	235	127	144	95	93	194	51	138.3	287.3	0.85	2077
1984	76	74	80	99	126	95	159	124	100	36	91.6	193.1	0.83	2108
1985	74	107	90	104	156	132	71	191	36	96	100.3	137.8	0.70	1374
1986	45	53	131	175	119	103	87	114	78	35	73.8	115.2	0.60	1561

Table 2.4. The number of vessels that reported qualified handline-troll landings between 1979 and 1986 by year of entry into the fishery. Each row gives the number of vessels that reported landings in the year specified by the column headings and which entered the fishery in the year specified by the row headings.

Year of entry	Year of reported landings							
	1979	1980	1981	1982	1983	1984	1985	1986
1979	253	101	88	89	75	51	25	28
1980		104	25	24	21	18	11	9
1981			93	22	11	9	7	5
1982				91	17	11	4	4
1983					50	8	4	4
1984						59	11	9
1985							30	4
1986								20
	253	205	206	226	174	156	96	83

Table 2.5. Sport landings of lingcod (t)[a] from the Strait of Georgia by minor statistical area, 1980-86[b].

	Minor Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Total
1980	41.8	12.6	2.4	22.6	12.6	9.6	13.8	4.6	6.7	126.7
1981	43.4	17.1	8.0	15.4	9.1	12.6	23.0	7.4	9.8	145.8
1982	24.0	9.1	2.1	31.4	14.2	9.6	20.3	9.8	5.9	126.4
1983	25.8	3.7	1.8	32.2	11.4	10.1	15.7	10.9	6.9	118.3
1984	63.5	18.2	2.7	45.9	26.2	11.4	26.4	14.2	13.0	219.8
1985	37.1	9.9	1.4	22.4	14.2	4.5	20.8	5.0	4.3	123.7
1986	41.3	15.5	2.1	15.0	10.1	6.9	17.1	3.0	2.6	113.6

[a] An average weight of 1.6 kg was used to convert numbers to weight.
[b] Source: Shardlow and Hoyt, unpublished data.

Table 2.6. Lingcod trawl landings, line landings, combined landings, qualified LPUE and equivalent effort for Area 3C, 1956-87.

Year	Trawl (t)	Line (t)	Tot Land (t)	LPUE (kg/h)	Effort (h)
1956	1151	156	1307	292	4478
1957	1070	295	1365	307	4449
1958	1047	156	1203	442	2719
1959	1742	113	1855	408	4543
1960	1867	219	2086	293	7114
1961	1972	136	2108	426	4949
1962	890	228	1118	291	3847
1963	609	147	756	462	1637
1964	1127	101	1228	437	2811
1965	1812	122	1934	398	4861
1966	2030	158	2188	329	6641
1967	1779	246	2025	408	4960
1968	1661	156	1817	584	3114
1969	1054	171	1225	298	4113
1970	703	286	989	291	3398
1971	979	231	1210	346	3495
1972	625	267	892	278	3214
1973	876	185	1061	364	2917
1974	1029	224	1253	240	5218
1975	1630	216	1846	292	6325
1976	1205	253	1458	204	7138
1977	844	267	1111	236	4698
1978	360	91	451	184	2452
1979	602	82	684	220	3112
1980	623	97	720	242	2979
1981	603	240	843	179	4703
1982	1510	221	1731	331	5230
1983	970	170	1140	314	3626
1984	1731	128	1859	391	4749
1985	3416	207	3623	469	7729
1986	836	241	1077	325	3312
1987	176[a]	51[b]			

[a] To Aug. 11, 1987.
[b] To June 30, 1987.

Table 2.7. Lingcod trawl landings, line landings, combined landings, qualified LPUE and equivalent effort for Area 3D, 1956-87.

Year	Trawl (t)	Line (t)	Tot Land (t)	LPUE (kg/h)	Effort (h)
1956	168	135	303	421	707
1957	130	146	276	583	470
1958	109	130	239	723	314
1959	64	102	166	563	276
1960	87	115	202	769	244
1961	200	125	325	544	550
1962	286	112	398	285	1334
1963	115	132	247	365	664
1964	226	92	318	536	578
1965	505	97	602	381	1457
1966	585	147	732	579	1177
1967	459	180	639	554	1098
1968	868	117	984	629	1400
1969	619	84	703	306	2053
1970	456	171	627	317	1922
1971	264	124	388	248	1548
1972	85	197	282	235	1168
1973	172	91	263	406	630
1974	242	123	365	509	677
1975	347	97	444	251	1553
1976	245	98	343	302	1108
1977	158	116	274	293	922
1978	197	94	292	458	625
1979	147	110	257	310	809
1980	127	94	222	199	1074
1981	87	122	209	170	1014
1982	49	175	224	188	1119
1983	447	153	600	299	1944
1984	322	153	475	204	2241
1985	380	194	574	456	1199
1986	244	229	473	306	1458
1987	20[a]	57[b]			

[a] To Aug. 11, 1987.
[b] To June 30, 1987.

Table 2.8. Number of lingcod sampled and tabular histograms of the weight-frequency distribution scaled from 0-10 by year for lingcod sampled from Area 3C, 1956-86. Weight intervals are 0.5 kg, with the last interval including all lingcod of 15.5 kg and greater. A '.' represents 0 and '*' represents 10.

		Weight (kg)																												
Year	No.		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15	+
1956	168	.	.	.	1	6	*	*	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1957	1889	.	.	.	1	3	8	*	7	*	4	4	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1958	1268	.	.	1	5	*	*	6	6	9	2	4	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1959	1493	.	.	.	6	8	*	5	4	4	.	1	2	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1960	1455	.	.	.	4	9	*	4	4	3	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1961	3448	.	.	2	6	8	*	7	5	5	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1962	2687	.	.	1	9	*	*	7	7	*	3	6	6	5	2	3	1	1	2	1	1	1	.	.	.	.	.	.	.	.	.	.
1963	1095	.	.	.	3	6	9	7	6	*	4	8	8	7	2	4	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1964	2266	.	.	.	3	7	*	8	8	9	3	4	3	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1965	3606	.	.	.	7	*	*	4	3	4	1	3	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1966	3560	.	.	.	6	*	*	7	5	5	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1967	2229	.	.	.	5	7	*	6	7	9	3	4	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1968	767	.	.	2	*	9	6	4	3	6	1	3	4	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1969	2684	.	.	.	6	*	*	4	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1970	1667	.	.	.	3	7	*	6	6	6	1	2	2	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1971	1491	.	.	.	1	1	4	6	6	*	3	6	4	3	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1972	572	.	.	1	5	5	4	3	2	6	3	9	*	*	6	7	3	1	3	1	1	.	1	.	2	.	.	.	.	.	.	.
1973	1682	.	.	1	8	9	*	6	4	8	2	5	4	6	4	7	4	3	5	1	2	2	1	2	1	1	1	1	1	1	.	3
1974	1669	.	.	1	7	*	*	5	3	4	1	3	3	3	.	2	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.
1975	595	.	.	2	*	8	6	9	3	4	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1976	860	.	.	1	3	4	4	9	5	8	6	*	5	3	1	1	.	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.
1977	260	.	.	.	3	4	5	8	3	9	4	*	*	6	4	3	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1978	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1979	285	.	.	3	2	8	*	9	2	*	6	7	5	4	5	3	.	4	3	.	1	.	.	.	.	.	.	.	.	.	.	.
1980	587	.	.	.	3	4	4	*	4	8	3	5	2	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1981	437	.	.	6	*	5	3	6	3	3	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1982	450	.	.	1	6	8	*	9	3	5	3	2	2	1	2	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1983	270	.	.	.	3	8	6	*	5	5	3	4	2	1	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1984	675	.	.	1	3	5	6	*	5	6	4	3	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1985	1214	.	.	4	6	5	4	*	6	9	5	7	5	4	4	2	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1986	391	.	.	1	8	*	7	5	4	4	2	5	4	3	4	1	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.

Table 2.9. Number of lingcod sampled and tabular histograms of the weight-frequency distribution scaled from 0-10 by year for lingcod sampled from Area 3D, 1956-86. Weight intervals are 0.5 kg, with the last interval including all lingcod of 15.5 kg and greater. A '.' represents 0 and '*' represents 10.

		Weight (kg)																														
Year	No.		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15 +	
1956	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1957	187	.	.	.	.	1	4	6	7	*	3	8	5	5	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1958	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1959	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1960	443	.	.	.	3	*	*	5	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1961	206	.	.	.	.	1	4	5	6	*	2	4	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1962	75	.	.	.	.	.	1	1	7	9	3	*	3	9	9	3	4	4	2	3	.	3	1	2	2	.	1	2	1	.	.	.
1963	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1964	1611	.	.	.	2	4	9	8	8	*	3	6	5	3	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1965	2767	.	.	.	2	9	*	5	5	6	2	3	3	2	1	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1966	3381	.	.	.	2	6	*	8	7	7	2	3	2	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1967	2482	.	.	.	4	9	*	7	7	*	3	5	4	3	1	2	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1968	2251	.	.	.	5	7	8	6	7	*	3	6	6	4	1	3	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1969	1568	.	.	.	6	*	9	3	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1970	853	.	.	.	2	5	*	6	5	6	.	2	3	1	.	2	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
1971	585	.	.	.	3	7	9	7	*	*	2	6	8	3	1	2	1	1	2	.	.	.	1	.	1	.	.	.	.	.	.	.
1972	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1973	977	.	.	.	4	*	7	4	5	9	2	7	8	8	3	7	2	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.
1974	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1975	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1976	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1977	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1978	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1979	199	.	.	.	.	5	9	*	2	1	1	2	2	2	3	3	1	3	1	.	2	.	.	.	.	.	.	.	.	.	.	.
1980	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1981	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1982	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1983	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1984	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1985	190	.	.	.	.	.	1	6	5	9	*	9	6	8	4	7	1	2	1	1	3	.	4	2	1	2	.	1	1	.	3	3
1986	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 2.10. Relative abundance by year-class for lingcod from Area 3C aged commercial samples, 1977-85. Relative abundance is the product of LPUE (kg/h) and age-frequency.

Year	Relative abundance								
Age	77	78	79	80	81	82	83	84	85
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	15.3
3	3.6	33.9	0.0	9.9	29.1	19.1	2.3	37.0	70.5
4	8.2	39.1	2.3	16.9	33.6	70.6	29.1	68.8	68.2
5	20.9	29.2	15.4	77.5	28.7	81.6	83.7	120.5	82.3
6	33.6	19.3	30.1	56.5	28.7	72.8	90.7	98.8	92.9
7	65.4	25.7	37.1	35.9	25.4	46.3	45.4	32.9	76.4
8	57.2	17.5	45.5	24.3	12.3	18.4	33.7	11.8	27.0
9	25.4	6.4	32.4	12.8	10.6	6.6	11.6	5.9	18.8
10	10.9	2.9	28.6	5.4	4.9	8.1	9.3	4.1	5.9
11	5.4	5.3	13.9	1.2	3.7	2.9	2.3	1.8	7.1
12	1.8	2.3	7.7	1.2	0.8	1.5	2.3	1.8	3.5
13	0.9	0.6	3.9	0.4	0.4	0.7	2.3	2.4	0.0
14	1.8	0.6	1.5	0.0	0.4	0.7	1.2	0.6	0.0
15	0.0	0.6	1.5	0.0	0.0	0.0	0.0	0.6	0.0
16	0.9	0.0	0.0	0.0	0.0	0.7	0.0	0.6	1.2
17	0.0	0.6	0.0	0.0	0.4	0.7	0.0	0.0	0.0
No.	260	315	285	587	437	459	270	665	399

Table 2.11. Lingcod trawl landings, line landings, combined landings, 25% qualified LPUE and equivalent effort for Area 5A and Area 5B, and Area 5A/B qualified LPUE and equivalent effort, 1956-87.

	Area 5A				Area 5B				Area 5A/B		
Year	Trawl (t)	Line (t)	Comb. (t)	LPUE (kg/h)	Trawl (t)	Line (t)	Comb. (t)	LPUE (kg/h)	Land. (t)	LPUE (kg/h)	Effort (h)
1956	350	24	374	371	250	4	254	470	628	443	1418
1957	433	1	434	258	170	6	176	295	611	284	2136
1958	296	1	297	139	276	0	276	417	573	353	1614
1959	192	1	193	359	429	1	430	410	623	400	1546
1960	280	13	293	276	377	2	379	373	672	352	1904
1961	388	19	407	534	323	3	326	274	733	366	1965
1962	531	36	567	363	407	5	412	297	979	328	2940
1963	285	27	312	295	357	16	373	259	685	280	2420
1964	352	8	360	342	335	8	343	186	703	304	2275
1965	331	5	336	363	566	8	574	169	910	282	3149
1966	706	24	730	349	826	7	833	362	1563	351	4415
1967	759	22	781	322	901	5	906	477	1687	368	4547
1968	1227	17	1244	296	1043	11	1054	400	2298	302	7226
1969	617	28	644	139	517	9	526	233	1170	157	7267
1970	590	29	619	250	390	16	406	255	1026	249	4088
1971	230	27	257	141	415	14	429	174	685	156	4363
1972	164	47	211	197	476	27	503	157	714	173	4127
1973	232	38	270	178	349	20	369	131	639	173	3694
1974	339	40	379	203	532	31	563	205	942	202	4640
1975	82	31	113	112	451	23	473	203	587	162	3623
1976	258	42	300	244	345	28	373	174	673	194	3469
1977	122	50	172	117	257	18	275	195	446	156	2841
1978	128	20	148	224	162	12	174	168	322	189	1695
1979	100	32	132	186	242	12	254	179	386	166	2144
1980	108	33	141	103	302	12	314	174	455	137	2844
1981	183	33	216	227	548	12	560	237	776	216	3302
1982	468	35	503	249	580	9	589	239	1091	237	4490
1983	573	37	610	267	772	10	782	337	1392	307	4505
1984	261	47	308	190	455	10	465	198	773	188	3964
1985	408	45	453	255	469	23	491	236	944	227	3869
1986	640	41	681	345	1012	7	1019	403	1700	366	4474
1987	344[a]	20[b]			404[a]	2[b]					

[a] To Aug. 11, 1987.
[b] To June 30, 1987.

Table 2.12. Number of lingcod sampled and tabular histograms of the weight-frequency distribution scaled by year from 0-10 for lingcod sampled from Area 5A/B, 1956-86. Weight intervals are 0.5 kg, with the last interval including all lingcod of 15.5 kg and greater. A '.' represents 0 and '*' represents 10.

Year	No.	Weight (kg) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 +
1956	128	. . . . 2 9 7 5 9 3 4 2 6 2 * 2 7 3 3 5 8 4 3 5 2 2 2 . 2
1957	1523	. . . 1 1 2 7 * 7 6 6 5 2 2 2 . 1 1 1 . . . 1 . . . .
1958	1483	. . . 1 7 7 7 * 7 6 5 7 1 3 3 1 1 . 1 . 1 . 1 1 . . . .
1959	1470	. . . 1 5 * 9 8 4 3 4 3 2 3 2 1 2 1 2 . 1 1 1 . . . .
1960	1747	. . . . 4 * 9 6 2 1 1 1 . 1 1 1 1 . 1 . . . .
1961	4242	. . . 2 3 4 8 * 6 5 4 3 1 2 1 1 1 . 1 . . . .
1962	4641	. . . 3 6 7 7 * 7 8 7 6 2 4 4 1 3 1 2 1 . 1 1 . . . .
1963	3239	. . . 2 4 6 8 * 7 7 7 6 3 5 4 1 2 1 1 . . . .
1964	2365	. . . 2 6 8 9 * 7 5 4 3 1 3 3 1 1 . 1 . . . .
1965	2078	. . . 3 6 * 8 4 3 3 3 3 1 1 2 . 1 . 1 . . . .
1966	3129	. . . 1 3 7 * * 5 4 3 2 1 1 1 . . . .
1967	1595	. . . 1 2 4 7 * 8 8 8 5 1 3 1 . . . 1 . . . .
1968	1989	. . . 6 * * 7 7 6 4 3 2 1 1 1 . . . .
1969	1739	. . . 4 8 * * 7 3 3 3 2 1 2 2 1 2 1 2 1 1 . . . .
1970	795	. . . 1 4 9 9 * 7 6 4 3 1 2 2 1 2 1 2 1 . . 1 . . . .
1971	228	. . . 2 4 5 6 * 8 8 9 9 1 7 3 1 6 1 6 1 2 . 1 . . . .
1972	173	. . . . . . 8 2 * 6 5 * 8 4 * * 3 2 4 4 2 3 2 4 2 1 1 . . 2 2 .
1973	434	. . . . . 3 6 5 7 7 * 7 6 4 5 4 1 2 1 2 . . . .
1974	229	. . . . . 2 4 * * 6 8 * 5 2 5 3 3 2 1 . . . .
1975	0	. . . .
1976	90	. . . . . . 1 6 * 8 2 1 3 2 1 . . . .
1977	477	. . . . . . 1 2 3 4 * 5 7 4 4 3 3 2 2 1 2 2 . 1 . 1 . . . . . .
1978	91	. . . 1 * 6 3 5 5 6 5 7 2 4 2 1 1 2 . 1 1 2 . . 1 . 1 . 1 . .
1979	280	. . . . 1 5 5 * 9 5 7 7 5 5 4 9 1 7 1 1 1 9
1980	538	. . . * 4 2 3 3 3 3 1 2 . . . .
1981	1039	. . . 5 9 * 4 2 1 . . 1 . . . .
1982	702	. . . 5 6 9 * * 8 7 2 2 2 2 1 2 . . . 1 . . . . . 2 . 1 . . . 1
1983	600	. . . 1 7 * * * * * 7 7 2 1 1 1 1 1 . 1 . . . .
1984	0	. . . .
1985	657	. . 1 * 4 2 2 4 4 4 3 4 4 2 4 2 1 1 . . 1 . . . .
1986	813	. . 1 6 * * 5 3 4 6 3 6 3 3 4 4 2 2 . 1 . . . .

Table 2.13. Relative abundance by year-class for lingcod from Area 5A/B aged commercial samples, 1977-82. Relative abundance is the product of LPUE (kg/h) and age-frequency.

Year	Relative abundance					
age	77	78	79	80	81	82
2	0.0	0.0	0.6	0.3	0.0	0.0
3	3.9	7.8	1.2	19.4	9.6	7.4
4	7.7	12.9	0.0	22.2	41.3	18.9
5	14.8	28.5	0.0	33.5	55.3	37.2
6	29.9	36.2	6.0	23.5	43.5	56.7
7	32.0	28.5	17.5	18.8	23.2	33.2
8	27.8	7.8	33.2	10.3	10.3	14.3
9	16.6	7.8	25.4	6.5	14.4	13.7
10	13.4	10.4	20.5	1.5	6.6	13.2
11	5.6	20.7	13.3	0.8	4.1	11.4
12	3.5	15.5	13.9	0.0	1.5	10.3
13	0.4	2.6	10.3	0.3	2.6	4.6
14	0.0	7.8	7.2	0.0	1.8	2.3
15	0.0	0.0	7.8	0.0	0.4	6.9
16	0.4	0.0	6.0	0.0	0.7	3.4
17	0.0	0.0	1.8	0.0	0.0	0.6
18	0.0	0.0	0.6	0.0	0.4	2.9
19	0.0	2.6	0.6	6.1	0.4	0.0
No.	443	73	275	531	586	414

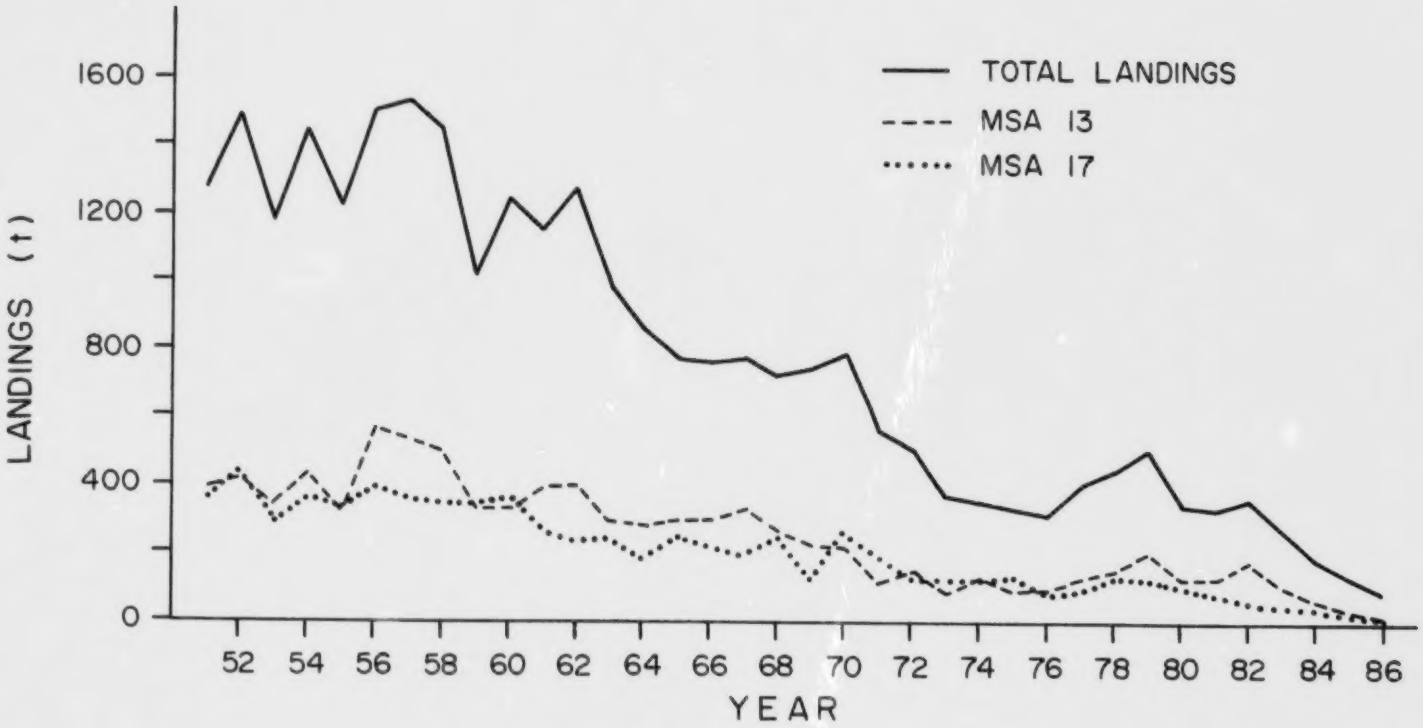

Fig. 2.1. Commercial handline/troll landings of lingcod showing the total landings from the Strait of Georgia and vicinity and from MSA 13 and MSA 17, from 1951-86.

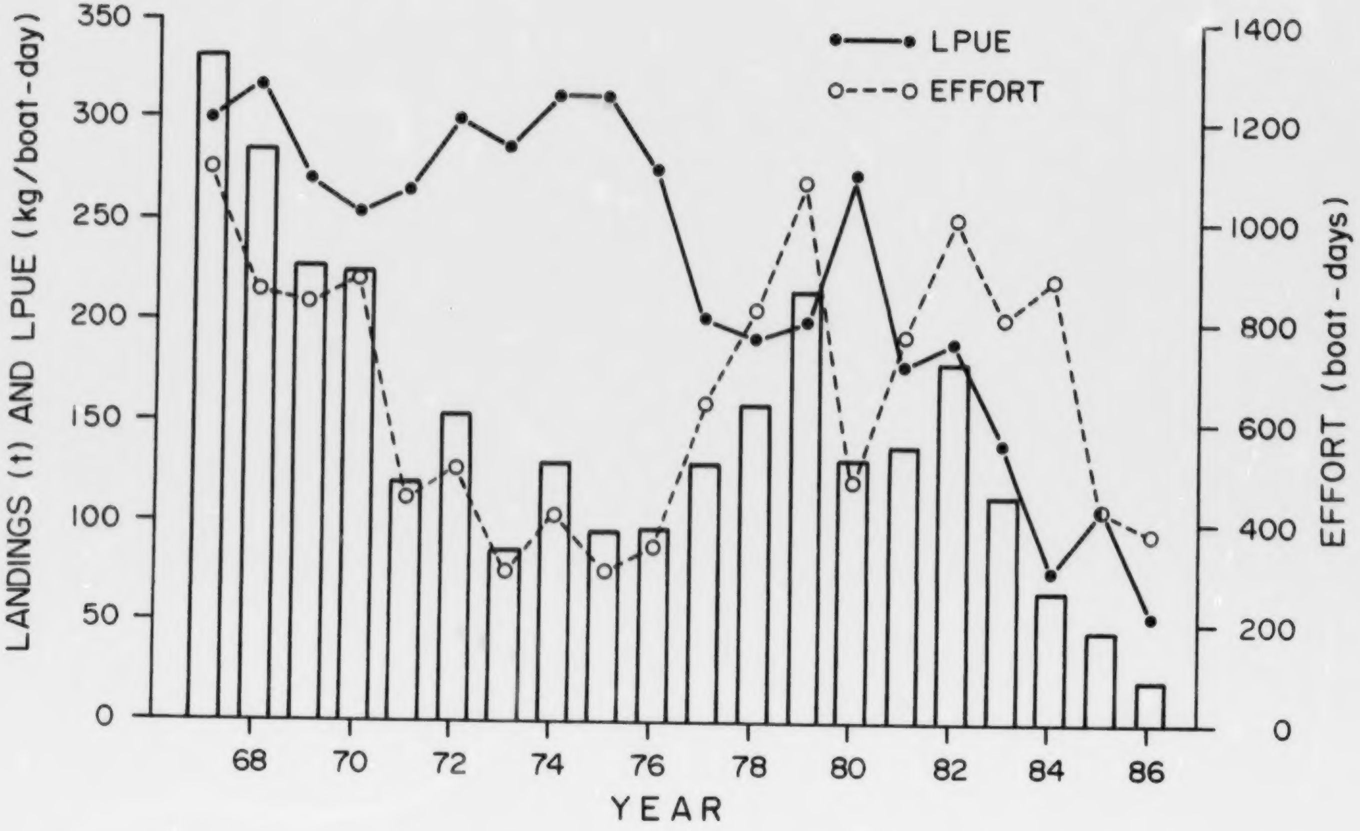

Fig. 2.2. Lingcod landing statistics in MSA 13 showing landings, LPUE and equivalent effort for commercial handline/troll fisheries, 1967-86.

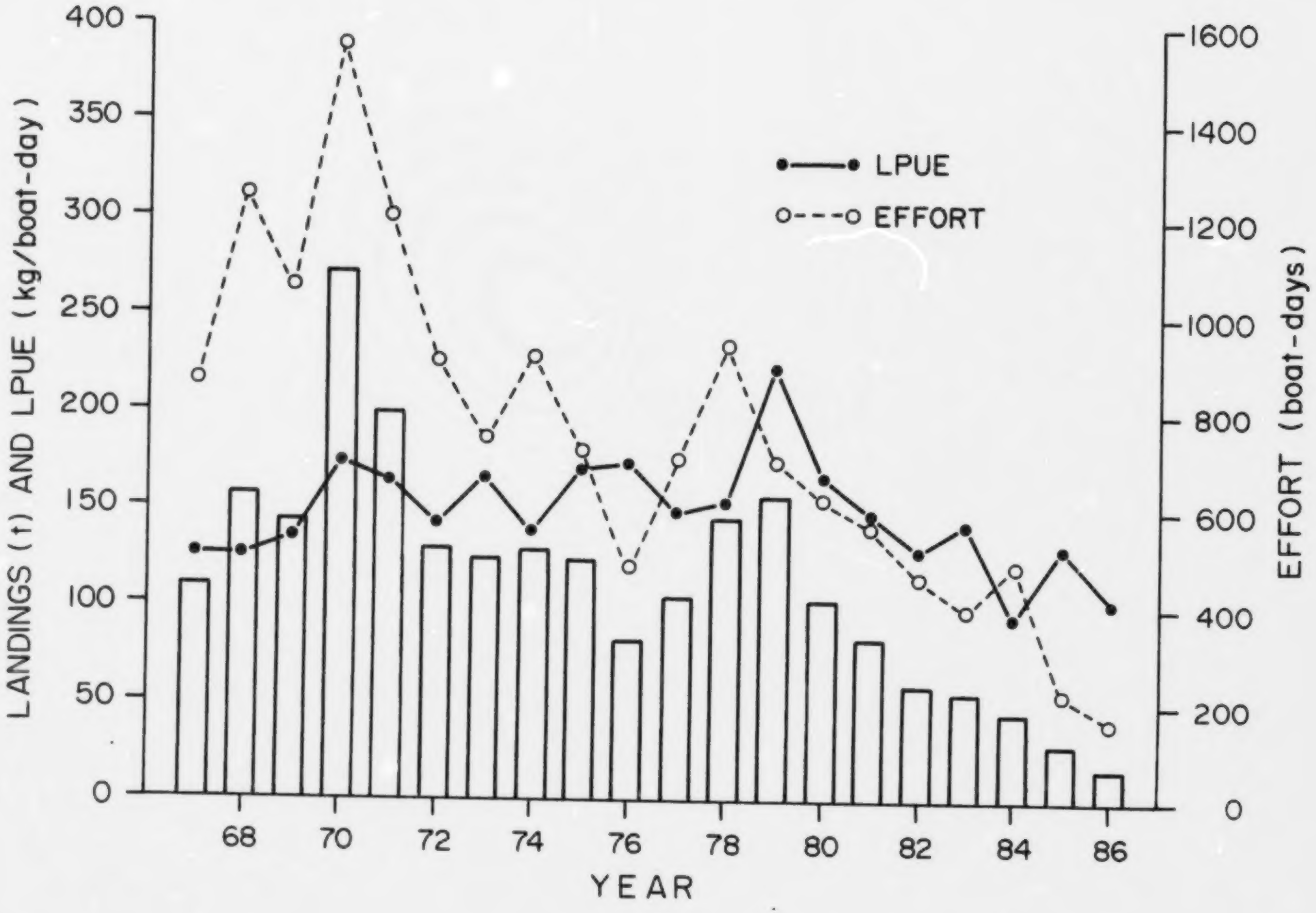

Fig. 2.3. Lingcod landing statistics in MSA 17 showing landings, LPUE and equivalent effort for commercial handline/troll and longline fisheries, 1967-86.

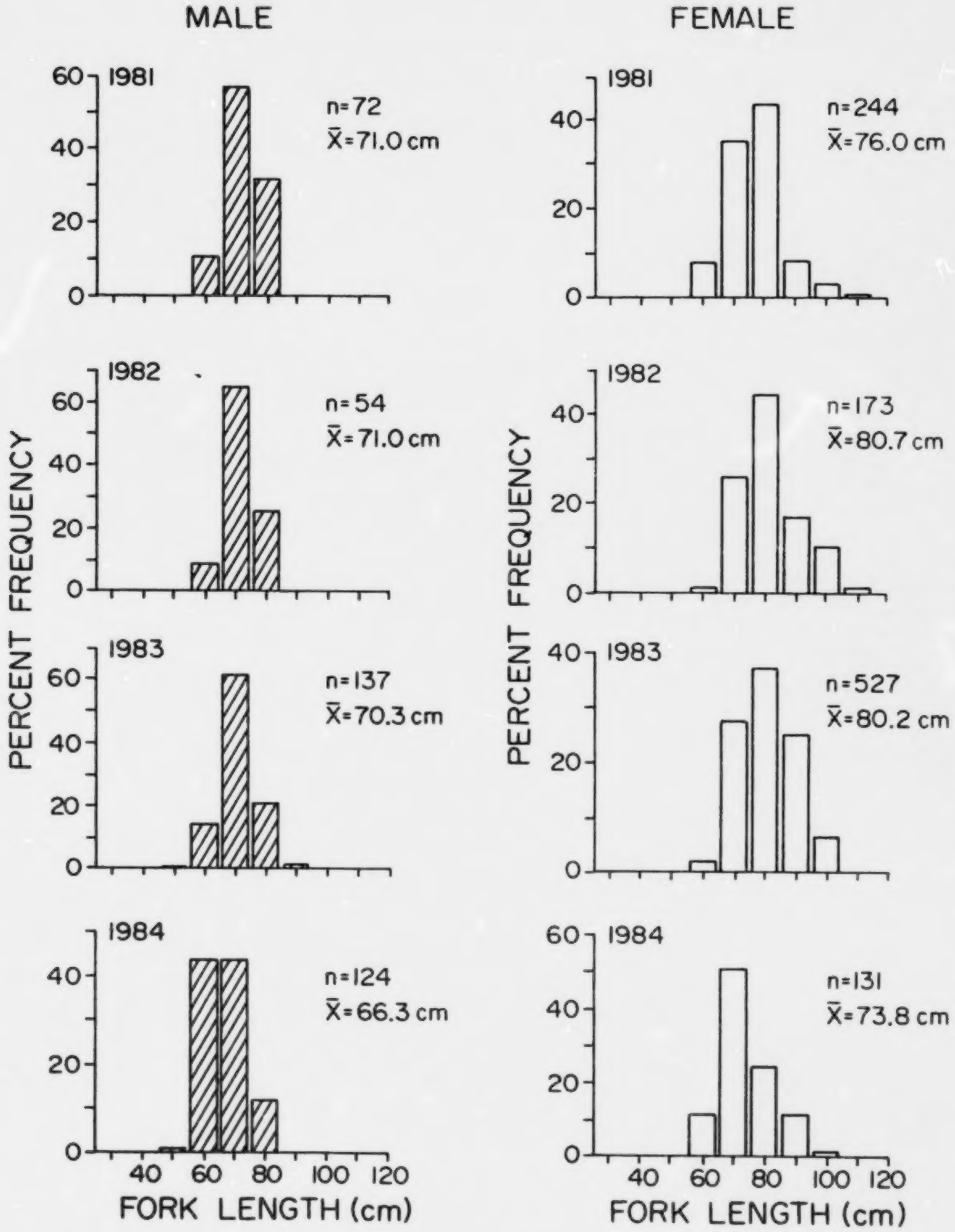

Fig. 2.4a. Length frequency histograms of lingcod in commercial handline samples from MSA 13, 1981-84.

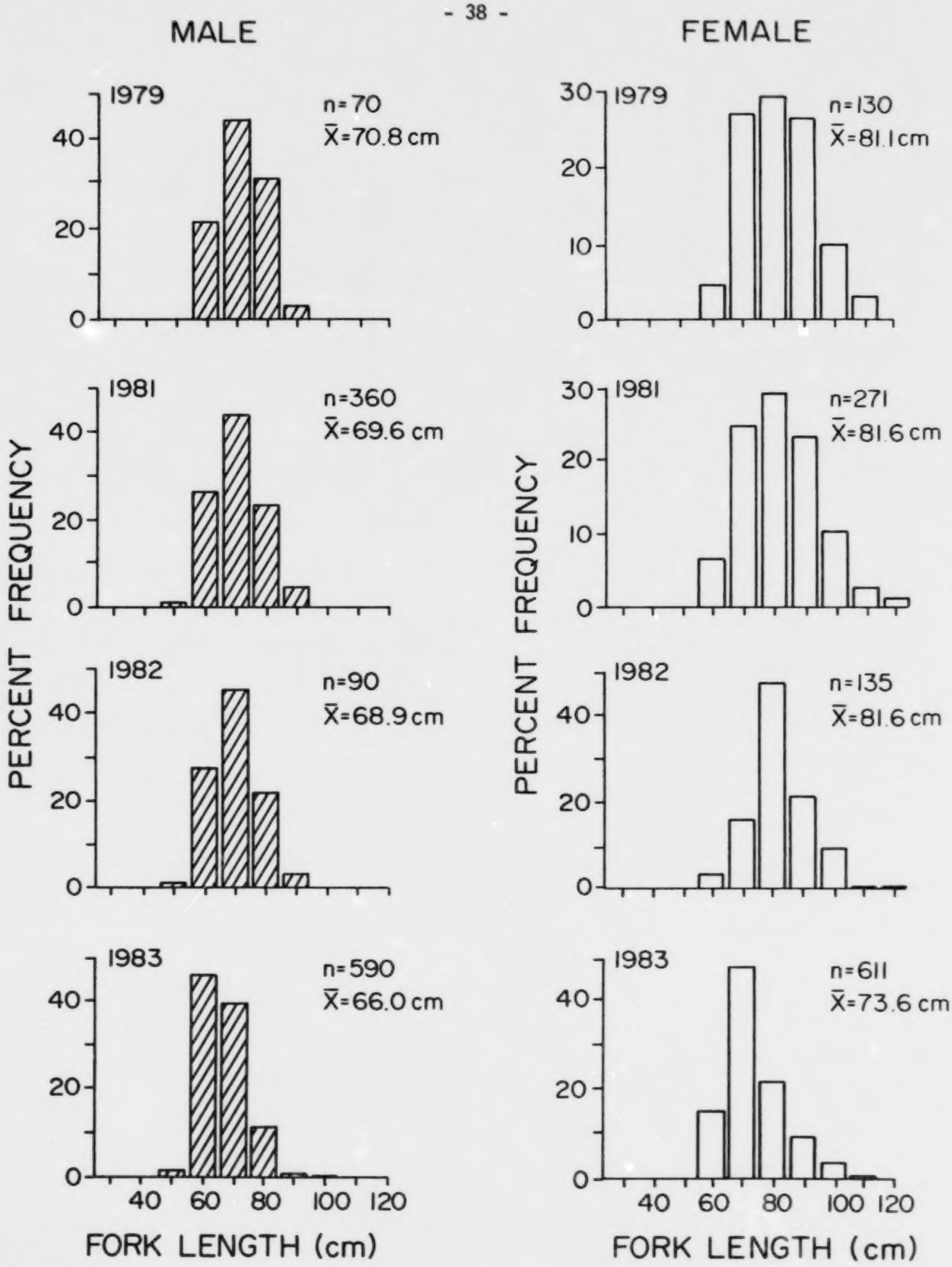

Fig. 2.4b. Length frequency histograms of lingcod in commercial handline samples from MSA 17, 1979-83.

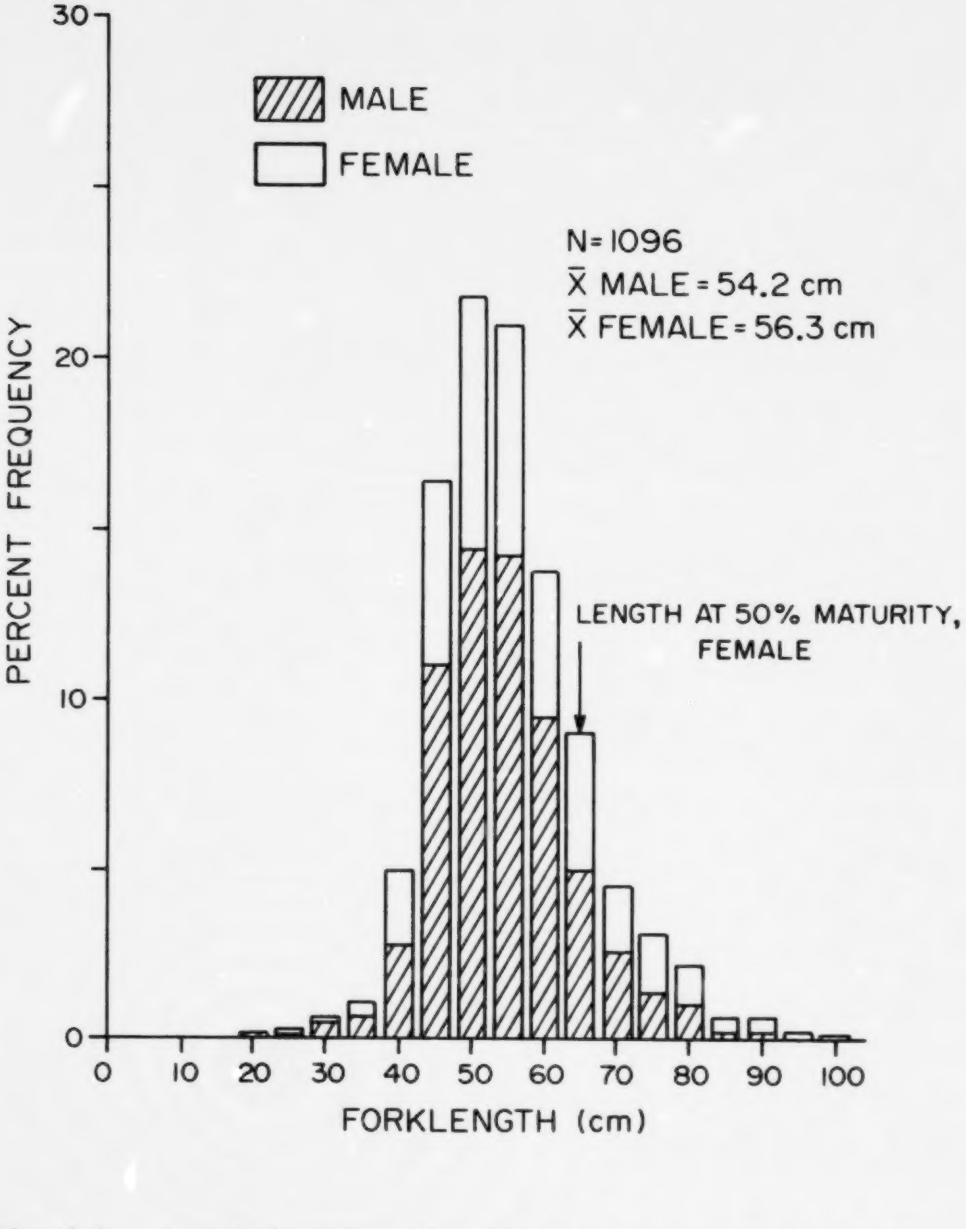

Fig. 2.4c. Length frequency histogram for lingcod caught in the sport fishery, 1983-87 combined.

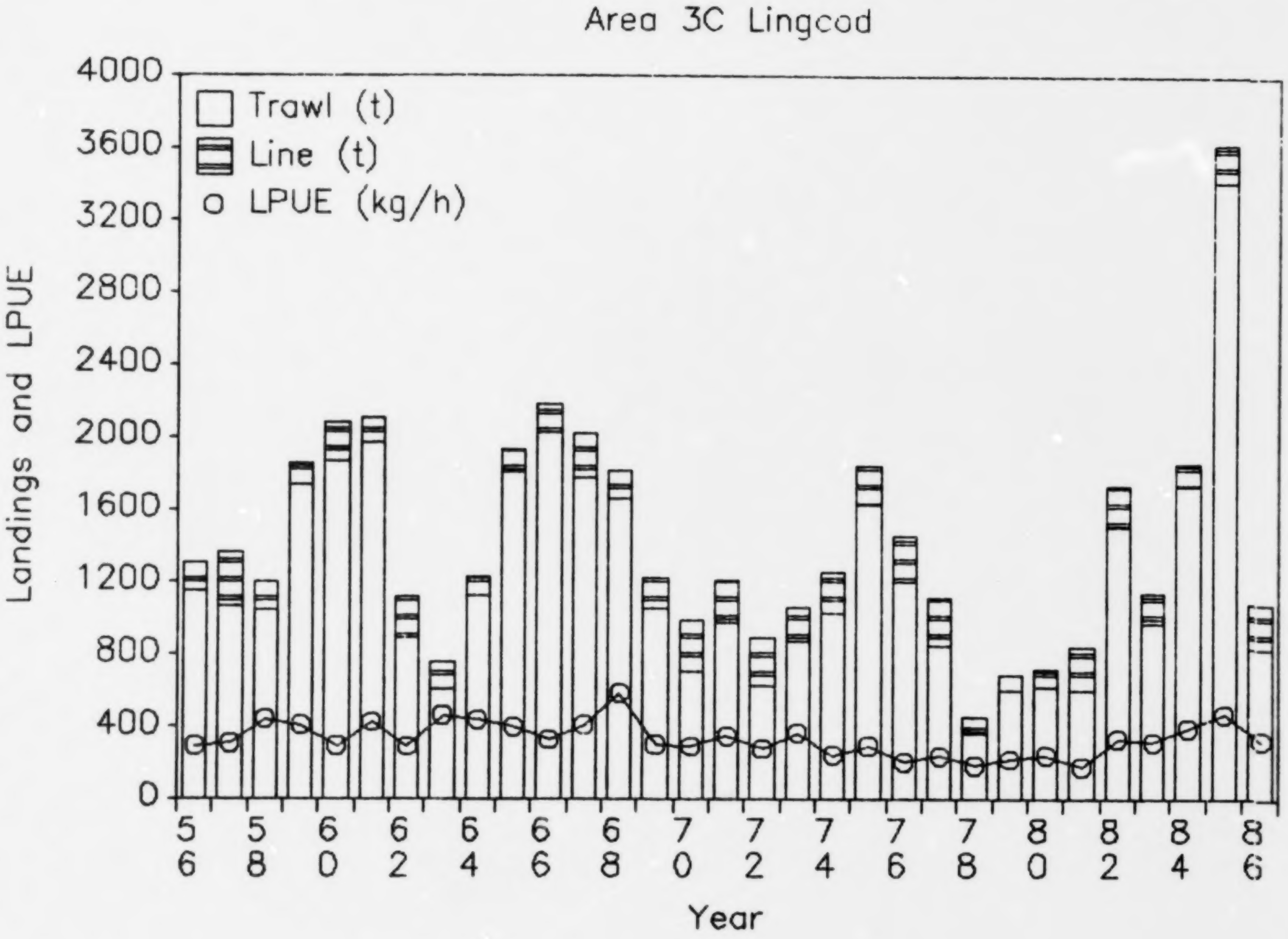

Fig. 2.5. Lingcod trawl landings, line landings, and qualified LPUE for Area 3C, 1956-86.

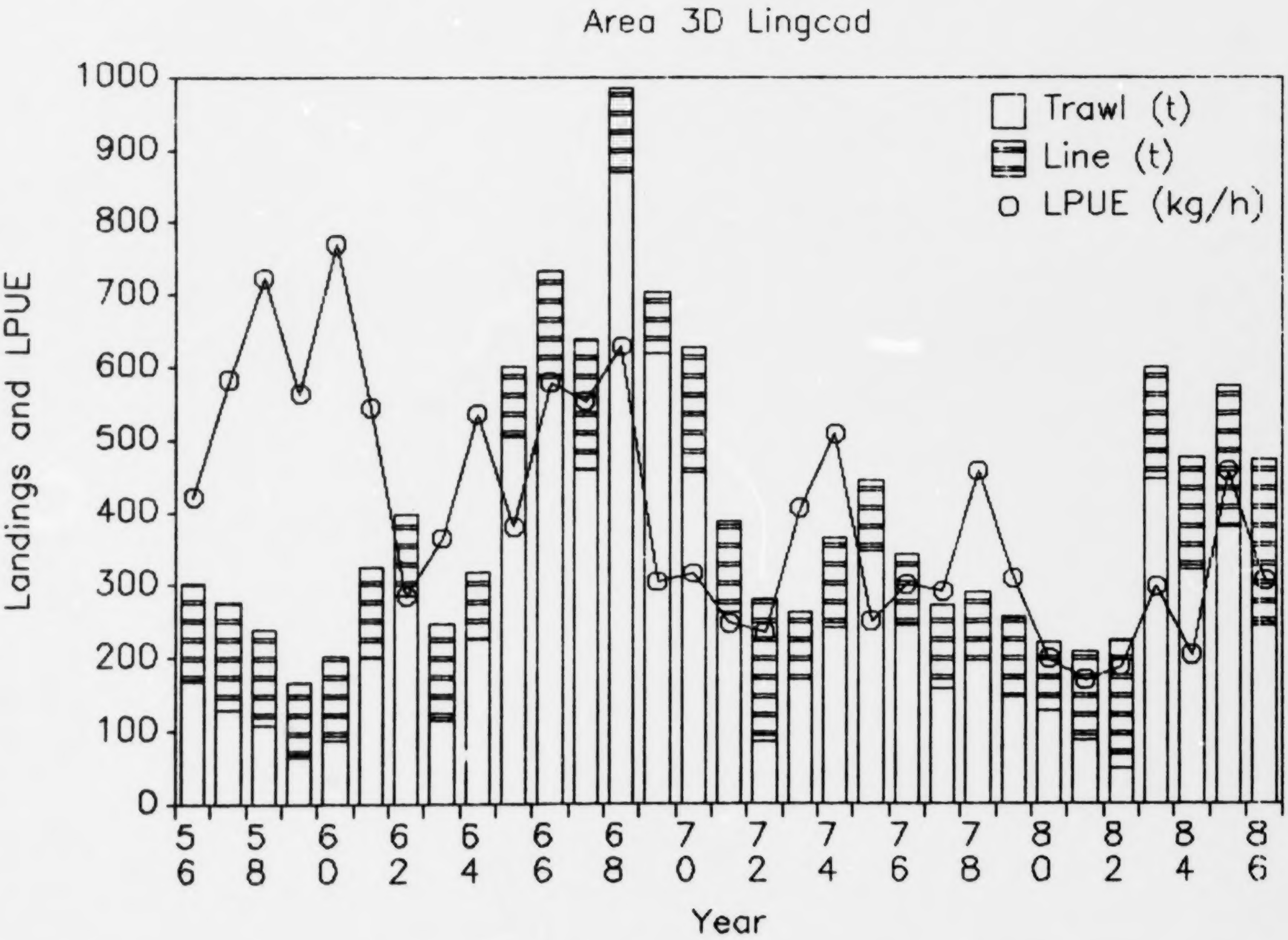

Fig. 2.6. Lingcod trawl landings, line landings, and qualified LPUE for Area 3D, 1956-86.

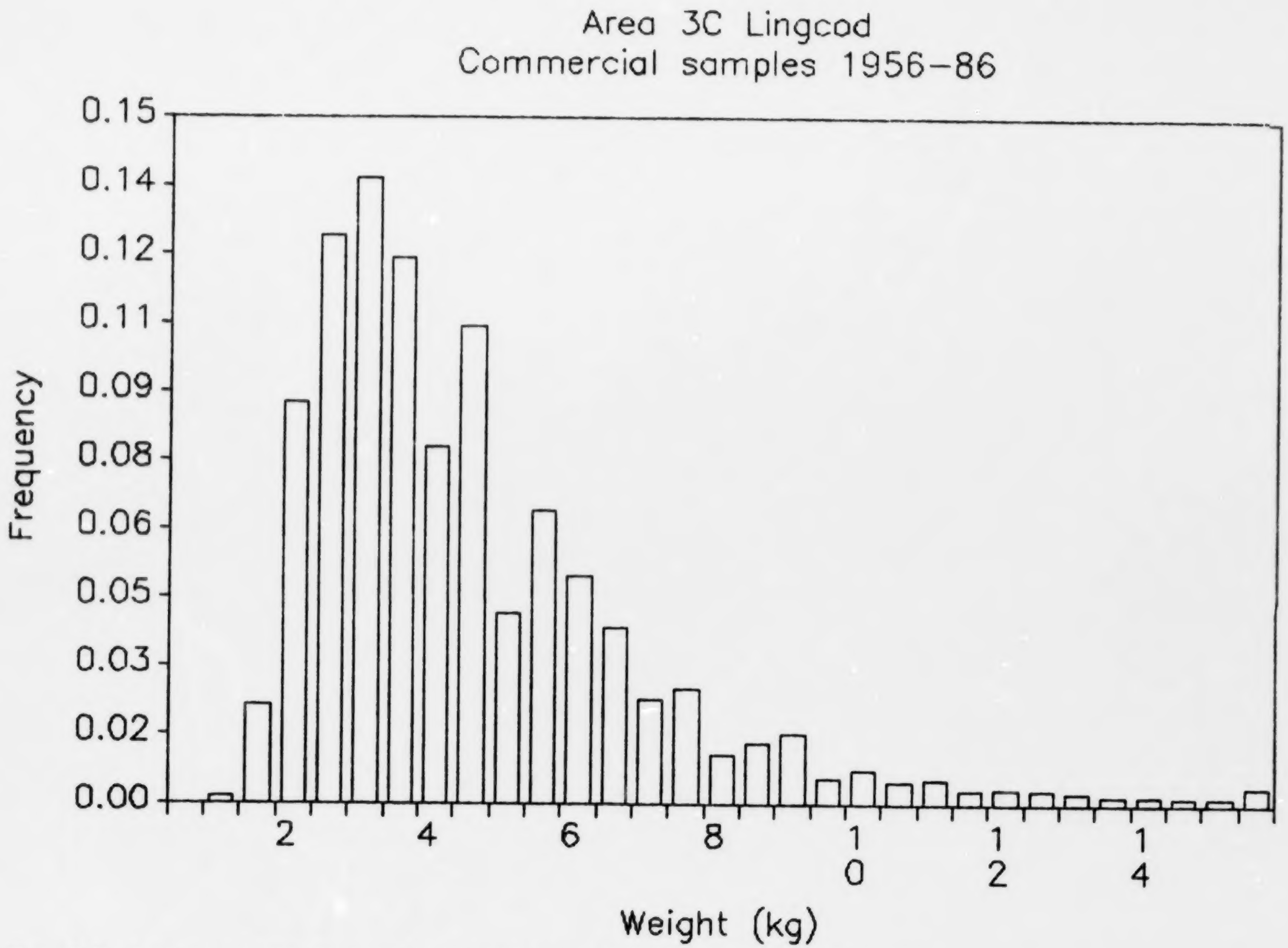

Fig. 2.7. Average weight-frequency distribution of Area 3C commercial lingcod samples, 1956-86.

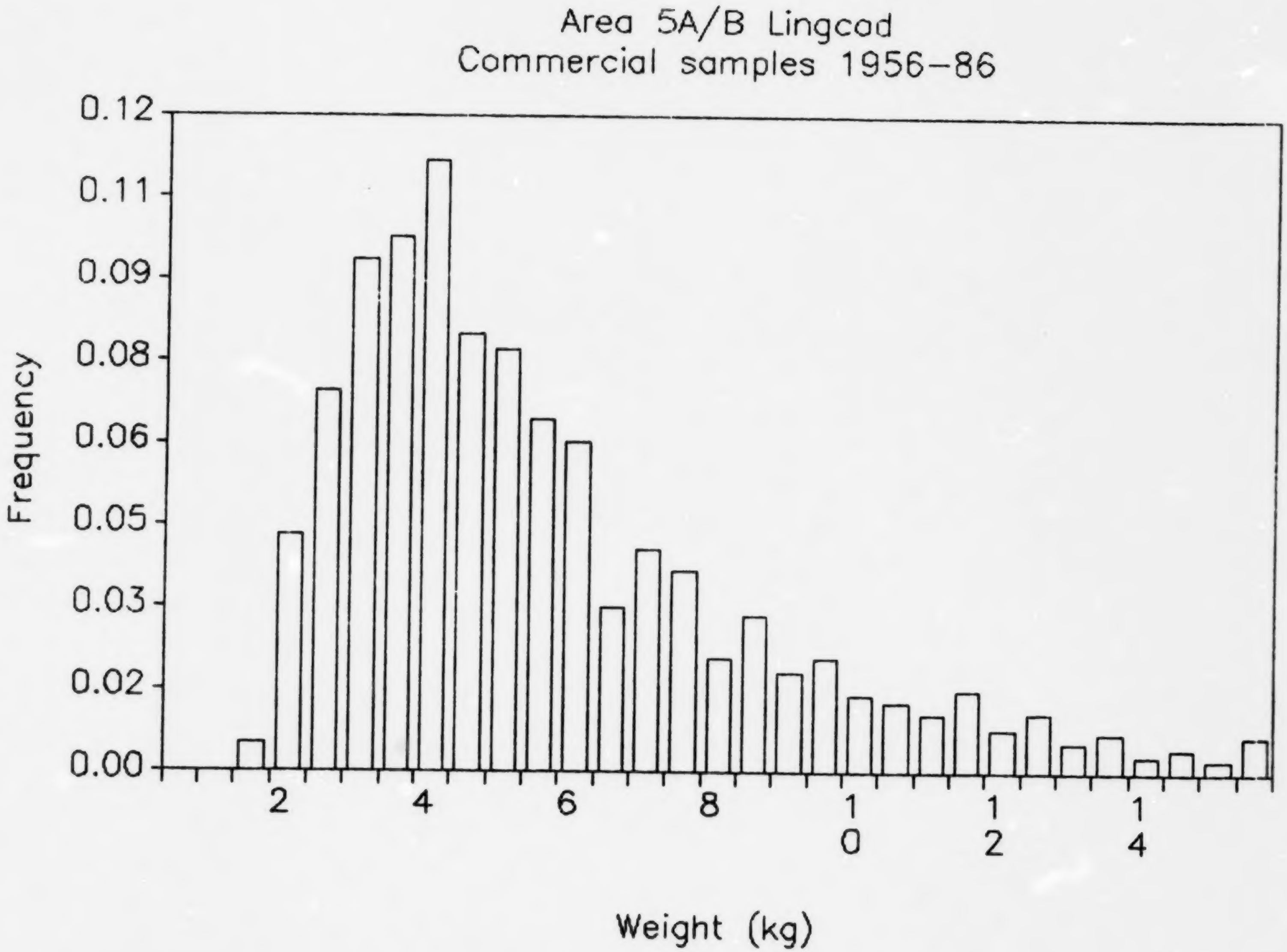

Fig. 2.8. Average weight-frequency distribution of Area 5A/B commercial lingcod samples, 1956-86.

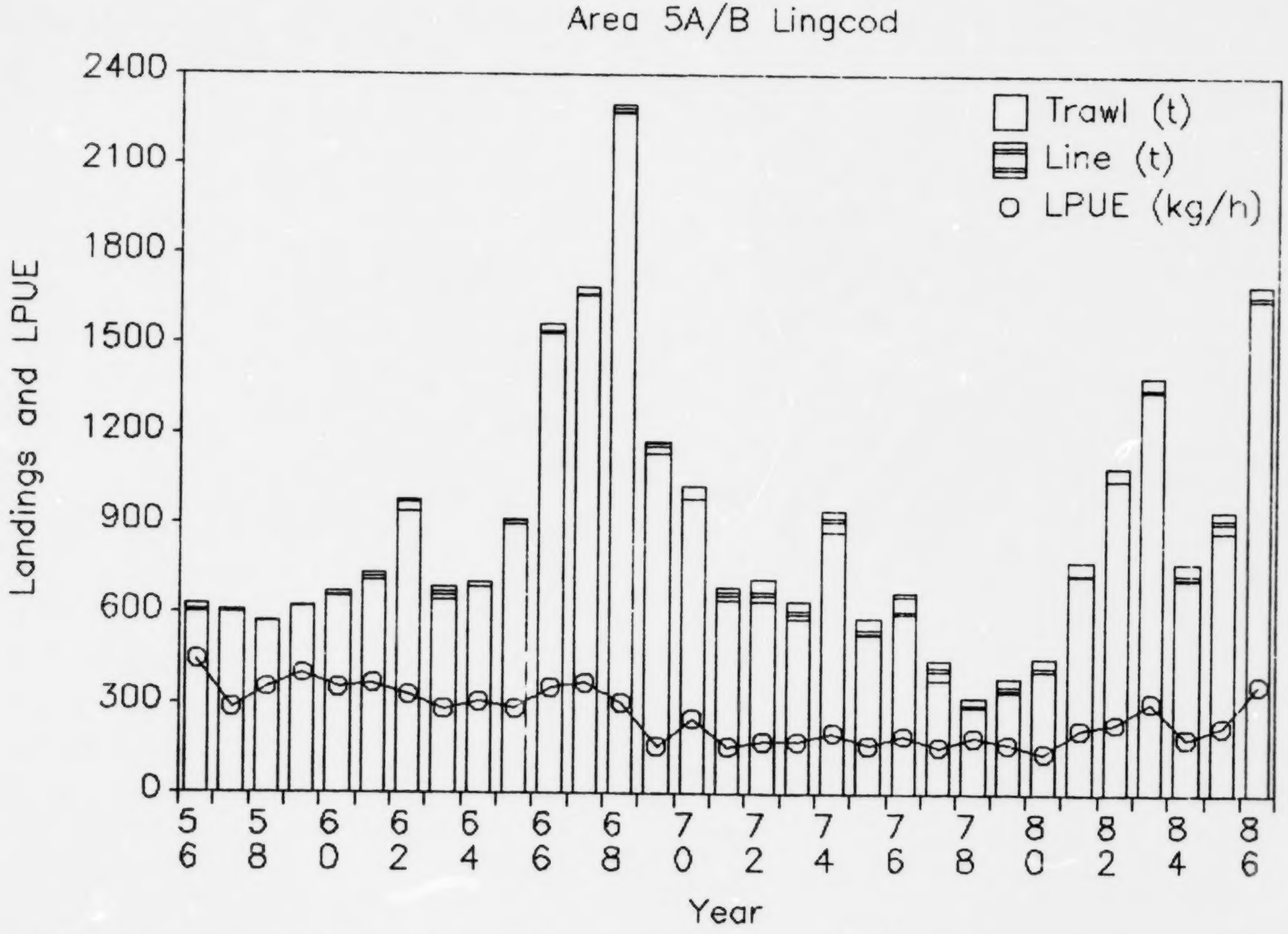

Fig. 2.9. Lingcod trawl landings, line landings, and qualified LPUE for Area 5A/B, 1956-86.

3.0. PACIFIC COD

R.P. Foucher and A.V. Tyler

3.0.1. General Introduction

Pacific cod (Gadus macrocephalus) has, historically, been a major component of the domestic, on-bottom trawl fishery. In Canadian waters, it is close to the southern limit of its commercial abundance. Pacific cod in this region has rapid growth and a short life span. Recruitment begins at age 2, most are recruited and mature at age 3, and few survive to age 7. Year-class strength varies considerably as reflected in the Canada-U.S. landings (Fig. 3.1).

Among regions, cod production is greatest in the most northerly, Hecate Strait, and negligible off the west coast of the Queen Charlotte Islands. Cod production has been low in recent years until an apparently strong 1985 year-class boosted production as it entered the fishery in early 1987.

3.1. Coastwide

Pacific cod were not treated as a coastwide stock.

3.2. Georgia Strait and vicinity

3.2.1. Introduction

A detailed stock assessment for this area was carried out in 1986 (Westrheim and Foucher 1987). No new analyses have been conducted since that time. Landings during 1986 were 803 t, an increase of 73% over 1985 (Table 3.1). Landings during January-June 1987 were 266 t down 25% over the same period in 1986. The strong 1985 year-class which is contributing to increased landings in other areas was apparently not doing so in this area. Landing statistics are summarized by calendar year, though previously they were presented by cod "year" (see section 3.2.2 for explanation).

By minor statistical area, landings increased in all areas except Area 20 (Strait of Juan de Fuca) in 1986 compared to 1985. The largest increase (220%) occurred in Area 19 (Victoria). In January-June 1987 landings increased in Areas 17, 18 and 20 and decreased in Areas 14 and 19, relative to January-June 1986. The largest change was the decrease in landings for Area 14 (40%) .

3.2.2. Yield options

Regulation does not appear to be necessary at this time. There are no symptoms of recruitment overfishing and current minimum mesh-size is reasonably satisfactory with respect to optimizing catch profitability (Westrheim and Foucher 1987).

3.3. West Coast of Vancouver Island (Areas 3C and 3D)

3.3.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery off the west coast of Vancouver Island. Area 3C produces approximately 90% of the Pacific cod, and Area 3D, 10% of the total landings for the two areas combined. Within Area 3C, principal trawling grounds are Amphitrite Bank (53% of Area 3C landings), Big Bank (28%), and Swiftsure Bank (14%) (Foucher and Westrheim 1984). Amphitrite Bank is a major spawning ground for cod, and 77% of its production historically (prior to 1980) occurs during January-March. Big Bank and Swiftsure Bank are feeding areas with production occurring primarily during April-September -- 79% and 89%, respectively. The trawl fishery on spawning cod began about 1961, assumed considerable importance after 1971, and has been subject to various conservation regulations since 1977.

3.3.2. Landing statistics

Landing statistics are based on Foucher (1987) for detailed records by ground. Effort was allotted to the mixed-species fishery using the method of Westrheim (1983), and standardized according to the method of Westrheim and Foucher (1985b). Essentially, the standardization was a linear function utilizing vessel horsepower as the single factor in the regression. Representative LPUEs for the region were derived from Canadian records for Big Bank, April-September. Landings, effort and LPUE have all fluctuated substantially (Table 3.2; Fig. 3.2).

Landing statistics have been, starting in this report, assembled by calendar year rather than by the April-March cod "year" used earlier (Westrheim and Foucher 1985). The stated reason for using the earlier system was "Recruitment begins with age-2 cod in April, and generally concludes the following January-March when these cod spawn for the first time at age 3." Reasons for the change are: 1) calling all fish of a year-class caught in a calendar year the same age follows the adopted convention of a January 1 birthday for all fish aged at the Pacific Biological Station (Chilton and Beamish 1982); 2) cod may be recruiting earlier now than in the past. In the port samples taken from White Rocks during January-March 1987 32% of the fish were 50 cm or less in length. The majority of these were likely age-2. This is biased by the strong 1985 year-class, however, the willingness of fish plants to take fish as small as 40 cm has been demonstrated; and 3) the bookkeeping for biological studies is greatly simplified. With either method, fish caught in January-March are attributed to the same year-class so differences in VPA results will be minimal. Abundance estimated from LPUE uses data from April-September only, and so is not affected by the change.

The trend in landings suggests a relatively steady decline in abundance after 1972-73. The steady decline in landings coincides with the initiation of a substantial fishery for spawning cod on Amphitrite Bank during January-March. During 1972-77, landings averaged 1,850 t (1,306-2,347 t)

(Foucher 1987; Appendix table 1), 45% of the annual mean production (3,897 t; 2,895-5,629 t) for the region (Areas 3C and 3D). Various conservation regulations have been imposed during January-March since 1977 which have substantially reduced trawling effort and landings in most cases. Landings to June 30, 1987 are 559 t compared to 357 t for the same period in 1986.

3.3.3. General biological information

Age composition

Age compositions are derived from length frequencies for Canadian cod landings using the method of Foucher and Fournier (1982). Age-classes 2-4 predominate in the landings, and few cod landed from the west coast of Vancouver Island are older than age 7 (Table 3.2). Recruitment is considered complete at age 3 under present fishery conditions. Year-class abundance during 1962-86, based on LPUE at age 2, fluctuates substantially--0.8 cod/h in 1985 to 125.6 cod/h in 1971. Data prior to 1962 are questionable due to the dissimilarity of the Canadian and U.S. trawl fleets at that time, and the absence of detailed records of the catches by U.S. vessels. Possible problems with accurately determining the proportions of older groups were pointed out by Westrheim and Foucher 1985.

Mortality rates

Because of possible variation in mortality rates with age and the possibility of ageing error, especially in the older age groups, mortality rates were calculated for successive pairs of ages to give estimates of the rates by age. Total instantaneous mortality rate was calculated using the equation $Z = \ln LPUE_i - \ln LPUE_{i+1}$. Natural mortality rate (M) was calculated by regression of Z on effort. The Y-axis intercept and the slope provide estimates of M and the catchability coefficient (q), respectively. The results are plotted for ages 4-5 in Figure 3.3 and are shown below:

Ages	Z	M	F	q	r
3-4	0.69	0.35	0.34	1.10×10^{-5}	0.164
4-5	1.19	0.69	0.50	1.57×10^{-5}	0.205
5-6	1.46	1.15	0.31	1.00×10^{-5}	0.096
6-7	1.36	0.73	0.63	1.99×10^{-5}	0.216

The relation between total mortality rate and year-class strength was investigated by regression of yearly Z estimates from age 3-4 on LPUE at age 3 (Fig. 3.4). This showed a significant relation between total mortality and LPUE: $Z = 0.319 + 0.0146$ (LPUE at age 3); $r=0.405$; $0.02<P<0.05$.

These results suggest that 1) age-3 fish are not historically fully recruited to the fishery, though they are this year -- see Section 3.5.4.; 2) total and natural mortality rates both increase with age; and 3) total mortality rate is positively related to year-class strength. It would appear to be hazardous therefore to use parameter estimates based on strong year-classes only as was done in Westrheim and Foucher (1985b) or on older year-classes with their higher estimates and relatively minor contribution to the fishery. The best estimates from the foregoing are considered to be those from ages 4-5: $Z = 1.19$, $M = 0.69$, and $F = 0.50$. Fish of these ages are old enough to be fully recruited but young enough for minimization of age-determination errors.

While the ageing data we have used is presently the best available it should be noted that there is an unknown degree of age-determination error associated with the data, especially for older fish. The apparent density dependent mortality rate, as well as the increase of mortality rate with age, could easily be due to errors in age-determination of older fish.

The age determination process is still under study. A comparison of age compositions derived by the length-frequency method, which was used to produce the time-series of ages used, and the fin-ray method is in progress. In addition, we plan a tagging experiment with injection of oxytetracycline to mark the fin rays for validation of their use for age determination.

The parameters were also estimated on a microcomputer utilizing software described in Walters (1986b) and based on Paloheimo (1980). Again Z was estimated using $Z = \ln LPUE_i - \ln LPUE_{i+1}$ as described in Paloheimo (1980). Paloheimo's method gave a much lower value for M at ages 3-4, but more similar values for ages 4-5 and 5-6. The historic partial recruitment of age-3 fish would account for the low mortality coefficients. M again appeared to increase with age:

Ages	Z	M	q
3-4	0.69	0.19	3.03×10^{-5}
4-5	1.19	0.67	2.95×10^{-5}
5-6	1.46	0.85	2.33×10^{-5}
6-7	1.36	0.22	6.85×10^{-5}

Virtual population analysis

A virtual population analysis (Gulland 1969) was undertaken utilizing the mortality rates estimated for ages 4-5: terminal F at age 7 = 0.50; M = 0.69 for all ages. Terminal F was allowed to vary around 0.50 by first calculating an overall q ($q = 0.50/E$ where E = mean effort), then calculating terminal F for each year ($F = qE$, where E is the effort for that year). Estimated numbers present (for age classes represented by ages 2-7 -- 1954-79) at age 2 ranged from 0.8 million in 1982 to 8.9 million in 1971 (Table 3.3). Mean values of F by age class were 0.09, 0.36, 0.56, 0.66, 0.65, and 0.50 for ages 2-7, respectively (Table 3.4). Mean exploitation rates for the time series were 0.06, 0.21, 0.30, 0.34, 0.29, and 0.28 for ages 2-7, respectively (Table 3.5).

3.3.4. Condition of the stock

The abundance index for Pacific cod off the west coast of Vancouver Island, calculated from the LPUE from Big Bank during April-September 1986 indicates an increase in abundance. The index increased from 13 kg/h in 1985 to 37 kg/h in 1986. Data for 1987 indicate it may be continuing to improve. LPUE for April-June 1987 is 284 kg/h, due in large part to the 1985 year class. While an improving trend is indicated, the 1986 LPUE of 37 kg/hr is still only at 15% of the average level during 1970-79. The increased LPUE in 1987 is based on provisional data for only one quarter and is largely due to the 1985 year-class which has not yet had opportunity to spawn and contribute to rebuilding the stock.

Yield-per-recruit analysis

The optimal yield-per-recruit was investigated using a minimum commercially acceptable size of 41 cm, a mesh size of 5.3 in. and natural mortality rates of 0.6, 0.7, and 0.8. The low minimum commercial size reflects the recent trend of plants to utilize the abundance of fish from the 1985 year-class which might otherwise be discarded at sea. The mesh size is an average of codend mesh sizes currently in use by the fleet. The resulting yield-per-recruit vs F curve for $M = 0.7$ (best estimate of $M = 0.69$) (Fig. 3.5) shows very little variation in yield-per-recruit above $F = 0.6$ (best estimate of $F=0.50$), but rapidly decreasing yield-per-recruit as F decreases below 0.6. At a lower value of M(0.6) yield-per-recruit rises more rapidly to a higher level, peaks at $F= 0.6$ and then drops more rapidly than when $M = 0.7$. Higher values of M lead to less yield per recruit as more fish die of natural causes.

3.3.5. Yield options

Until the stock has rebuilt toward historic levels, protection of the stock during spawning is warranted. We suggest that Amphitrite Bank, and a safe margin around it, be closed to all trawling during January, February, and March, 1988. This suggestion was implemented in both the 1986 and 1987 management plans. The closure is to protect cod when they are particularly vulnerable as they concentrate within a very limited area for spawning. The alternative of continuing the fishery on spawning fish could possibly prevent re-building of the stock.

3.4. Queen Charlotte Sound (Areas 5A and 5B)

3.4.1. Landing statistics

Landings in 1986 were 174 t from 5A and 67 t from 5B (Table 3.6), reductions of 4 and 43% respectively from 1985 landings. However, for the period January through June, 1987 landings rose dramatically to 829 and 797 t, for Areas 5A and 5B, respectively.

3.4.2. Condition of the stock

The 1984 assessment (Westrheim and Foucher 1985a) indicated there was little danger of recruitment overfishing because of extensive, rough-bottom refuges from trawling. The rise in landings in early 1987 reflects the contribution to the 1985 year-class as seen in other regions. No new analysis has been carried out.

3.4.3. Recommendation

No recommendation is made for the fishery in Queen Charlotte Sound.

3.5. Hecate Strait (Areas 5C and 5D)

3.5.1. Introduction

In the mixed-species trawl fishery of Hecate Strait, Pacific cod is the major contributor to the landings. The two species principally mixed with it, rock sole and English sole, have shown apparent reciprocal relationships to cod landings (Fig 3.6). However, in a recent study (Westrheim, Fargo and Foucher, in prep.) it has been shown that the low landings of rock sole and English sole during some periods of high cod landings may have been due to fishermen discarding these species in preference for the more abundant and desirable Pacific cod. They may also have avoided depths frequented by rock sole to concentrate their fishing effort in areas with greater Pacific cod abundance.

3.5.2. The fishery

Hecate Strait comprises two major areas--5C and 5D (Fig. 1). Area 5C produces 33% of the Pacific cod landed from Hecate Strait (Foucher 1987). Principal cod-producing grounds are Horseshoe (66%), Ole Spot (18%), and Reef Island-Cumshewa (14%) (Fig. 3.7). Cod occupy Horseshoe and Ole Spot grounds primarily during April-September; and Reef Island-Cumshewa during January-June. Area 5D produces 67% of the cod landed from Hecate Strait. Principal grounds are Two Peaks-Butterworth (54%) and White Rocks-Bonilla (31%). Cod occupy Two Peaks-Butterworth Ground principally during April-September and White Rocks-Bonilla during October-March.

3.5.3. Landing statistics

Effort (Table 3.7; Fig. 3.8) is fairly constant up to the mid-1960s, after which there is a series of irregular oscillations, likely in response to strong year-classes. Since 1982, effort has remained fairly constant at below 8000 h. Landings have also oscillated and show a pattern similar enough to that for Areas 3C and 3D to suggest that factors with a coastwide influence may be involved. Interestingly, effort has generally peaked about two years after landings have peaked, suggesting a lag time in the response of the fishery to changes in abundance. LPUEs also oscillate but not synchronously with landings. A long, downward trend in landings and LPUE since the mid-1970s appears to now be reversing. Abundance of cod, based on landing statistics, has recently been at very low levels but appears to be recovering, as the 1985 year-class enters the fishery. Landings to June 30, 1987 are 5460 t compared to 1898 t for the same period in 1986.

3.5.4. General biological information

Age composition

Annual age composition in numbers landed per hour trawled (Table 3.7) shows that ages 2-4 are most important to the fishery. Recruitment of age-2 fish begins historically in the spring, but more recently in the winter. In recent years, recruitment is complete by age 3, but in the past by age 4. Strong year-classes, based on LPUE at age 2 (>100/h), are 1961, 1962, 1965, 1970-72 and 1977. A strong year-class is also evident for 1985.

Mortality rates

Mortality rates were calculated in the same manner as for Areas 3C and 3D (see section 3.3.3). The results are plotted for ages 4-5 in Fig 3.9 and are shown below:

Ages	Z	M	F	q	r
3-4	0.63	0.24	0.39	2.71×10^{-5}	0.257
4-5	1.13	0.61	0.52	3.54×10^{-5}	0.352
5-6	1.22	0.69	0.53	3.65×10^{-5}	0.344
6-7	1.16	0.98	0.18	1.22×10^{-5}	0.082

The results suggest that M may increase with age. The parameters estimated for ages 4-5 are reasonable and also have the highest r value (0.352). They may be the best estimates for two additional reasons. Incomplete recruitment of age-3 fish in some years may have produced the low natural mortality rate for ages 3-4. Ketchen (1964) presents data which he says "suggest that the fishery is selective for the larger sizes of cod, most of those less than 50 cm in length being rejected at sea." In our time series the estimates for ages 4-5 are probably the first ones involving only fully recruited age classes. Also, because the likelihood of ageing error increases as fish age, the estimates for ages 4-5 are less likely to be affected by errors in age determination than those for older fish.

As for Areas 3C and 3D, the relationship between total mortality and year-class strength was investigated by regression of Z for ages 3-4 on LPUE at age 3 (Fig. 3.10). The result was $Z = 0.385 + 0.00200(\text{LPUE at age 3})$; $r = 0.332$; $0.05<p<0.10$. Although the relationship is not statistically significant the trend is the same as in Areas 3C and 3D -- increased total mortality rate with increased year-class strength.

The computations of parameters from selected strong year-classes as carried out by Westrheim and Foucher (1985) was not repeated. The possible danger of looking at only strong year-classes has been identified (section

3.3.3.). The best parameters are considered to be those calculated from ages 4-5: M = 0.61 and F = 0.52.

Using the method of Paloheimo (1980) as described in section 3.3.3 the following results were obtained. M again appeared to increase with age:

Ages	Z	M	q
3-4	0.63	0.19	3.03×10^{-5}
4-5	1.13	0.67	2.95×10^{-5}
5-6	1.22	0.85	2.33×10^{-5}
6-7	1.16	0.22	6.85×10^{-5}

Virtual population analysis

Virtual population analysis used parameters from ages 3-4, F = 0.52, M = 0.61. Terminal F was allowed to vary around 0.52 by first calculating an overall q (q = 0.52/E where E = mean effort), then calculating terminal F for each year (F = qE, where E is the effort for that year). The VPA estimates of cod at age 2 ranged from 2.8 million in 1968 to 16.3 million in 1964 (Table 3.8). Mean values of F by age class were 0.13, 0.39, 0.57, 0.61, 0.58 and 0.52 for ages 2-7, respectively (Table 3.9). Mean exploitation rates were 0.10, 0.24, 0.34, 0.35, 0.34, and 0.19 for ages 2-7, respectively (Table 3.10).

3.5.5. Condition of the stock

The abundance index for Pacific cod in Hecate Strait, calculated from the LPUE from Horseshoe and Two Peaks-Butterworth during April-September indicates an increase in abundance. The index increased from 151 kg/h in 1985 to 557 kg/h in 1986. Data for 1987 indicate a further improvement. LPUE for April-June 1987 is 1149 kg/h, due largely to the 1985 year-class. The 1986 LPUE is 79% of the long-term (1956-85) level and the 1987 LPUE is 168% of the long-term level, the highest value since 1966.

The optimal yield-per-recruit was investigated using a minimum commercially acceptable size of 41 cm, a mesh size of 5.3 in. and natural mortality rates of both 0.4 and 0.6. The low minimum commercial size reflects the recent trend of plants to utilize the abundance of fish from the 1985 year-class which might otherwise be discarded at sea. The mesh size is an average of codend mesh sizes currently in use by the fleet. The resulting yield-per-recruit vs F curve for M = 0.6 (best estimate of M = 0.61) (Fig. 3.11) shows very little variation in yield-per-recruit above F = 0.5 (best estimate of F =0.52), but rapidly decreasing yield-per-recruit as F decreases below 0.5. At a lower value of M(0.4) yield-per-recruit rises more rapidly to a higher level, peaks at F= 0.4 and then drops more rapidly than when M = 0.6. Under these conditions any changes in fishing pressure will have little effect on yield-per-recruit. The mean historic F was estimated at 0.52, giving support to the hypothesis that the fishery has been self-regulating in terms of yield-per-recruit.

3.5.6. Yield options

Alternative recommendations last year were 1) 900 t, conservative quota; 2) 1800 t, sustainable quota; or 3) no quota (risk sustainable) on the basis that the fishery is self-regulating. With the large increase in LPUE in 1987 due to the 1985 year-class, after an extended period of low abundance, we feel there is further evidence that the fishery is still self-regulating and that Pacific cod stocks have the capacity to recover quickly under favourable environmental conditions. We therefore are suggesting that there be no quota for the 1988 fishing year.

Table 3.1. Canadian annual landings (t) and standardized effort (h) for Pacific cod from the Strait of Georgia and vicinity (Area 4B), 1954-86.

Year	Landings (t)	Effort (h)
1954	1259	5634
1955	967	5202
1956	578	3487
1957	607	2772
1958	650	2873
1959	1047	3107
1960	744	2980
1961	415	2510
1962	479	1733
1963	677	2484
1964	713	3345
1965	484	2625
1966	297	2302
1967	475	2146
1968	349	2740
1969	388	2575
1970	502	2658
1971	740	2689
1942	630	1423
1973	441	955
1974	681	1370
1975	991	2019
1976	927	1983
1977	1148	2983
1978	1373	3327
1979	1197	2989
1980	1606	4843
1981	1742	3816
1982	1011	2217
1983	907	903
1984	652	319
1985	463	133
1986	803	360

Table 3.2. Canada-U.S. annual landings (t), standardized equivalent effort (h), overall LPUE and number/h, by age, for Pacific cod from the west coast of Vancouver Island (Areas 3C+3D), 1956-86.

Year	C-US Land (t)	C-US Eff (h)	C-US LPUE (kg/h)	Age									
				1	2	3	4	5	6	7	8	9	10
1956	1468	9009	163	-	8.6	21.1	19.9	9.0	0.8	0.6	0.3	-	-
1957	1814	13538	134	-	16.3	19.2	10.2	5.9	1.4	0.3	0.1	0.1	-
1958	850	7659	111	-	1.8	34.7	6.3	2.7	0.5	0.2	-	-	-
1959	907	20155	45	-	1.3	6.4	5.5	1.3	0.1	0.1	-	-	-
1960	635	10079	63	-	0.4	13.7	7.2	2.2	0.4	-	-	-	-
1961	420	19998	21	-	0.5	1.6	3.8	1.7	0.1	0.1	-	-	-
1962	633	16230	39	-	13.9	3.5	2.2	0.9	0.2	-	-	-	-
1963	1231	9770	126	-	33.9	17.5	7.2	1.5	0.2	0.2	-	-	-
1964	1221	3569	342	-	23.1	47.8	38.9	19.0	7.2	0.9	0.5	-	-
1965	2768	12361	224	-	15.4	47.5	20.6	5.5	1.7	0.4	0.1	-	-
1966	3136	13108	239	-	16.2	49.7	23.7	6.3	2.3	0.4	-	-	-
1967	1941	24887	78	-	2.2	16.8	7.9	1.3	1.0	0.1	0.1	-	-
1968	1425	17378	82	-	3.7	15.0	6.7	2.8	1.0	0.4	0.1	-	-
1969	1092	15825	69	-	5.0	12.2	5.3	2.3	1.1	0.4	0.2	-	-
1970	1095	7879	139	-	28.9	19.2	13.0	3.5	0.7	0.2	0.1	-	-
1971	3328	6631	502	1.4	125.6	86.0	18.0	5.7	1.7	0.9	0.4	-	-
1972	5629	10846	519	0.9	113.3	86.8	27.6	7.6	1.4	0.7	0.4	-	-
1973	3712	17345	214	-	9.7	35.9	19.6	6.4	2.3	0.4	0.1	-	-
1974	3474	18094	192	-	27.2	13.0	23.2	8.9	2.4	0.9	0.4	0.1	-
1975	4000	24847	161	-	13.8	36.2	9.2	4.3	2.1	0.3	0.2	-	-
1976	3797	21215	179	-	8.5	35.6	21.3	5.6	0.7	0.3	0.2	-	-
1977	2948	20192	146	-	11.5	21.0	16.0	5.3	1.8	0.5	0.2	-	-
1978	1998	11965	167	0.1	7.3	34.6	15.4	6.3	0.9	1.2	0.1	0.1	-
1979	1861	8461	220	0.1	26.2	32.7	19.5	8.7	1.5	0.6	0.2	0.1	-
1980	1152	9291	124	0.6	22.3	14.3	10.6	5.1	2.0	0.1	-	0.1	-
1981	918	15298	60	0.3	4.8	19.4	2.7	0.6	0.6	0.3	-	-	-
1982	1123	32086	35	-	2.7	6.6	3.7	1.2	0.4	0.2	-	-	-
1983	694	10516	66	-	16.3	7.2	8.6	1.9	1.3	0.1	-	-	-
1984	675	20455	33	-	4.1	6.8	3.2	1.3	0.2	0.1	-	-	-
1985	493	37923	13	-	0.8	4.6	0.8	0.1	-	-	-	-	-
1986	498	13459	37	-	2.1	4.7	6.3	1.2	0.2	-	-	-	-

Table 3.3. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age classes 2-7, 1956-86. (Asterisks indicate estimates of age-2 numbers at age considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope (1972).)

	Age					
Year	2	3	4	5	6	7
1956	1543	759	505	202	36	27
1957	1962	720	251	134	47	13
1958	1500	830	188	36	16	11
1959	2334	742	236	61	5	5
1960	1672	1154	283	45	14	1
1961	2461	833	483	93	8	4
1962	3127	1226	394	190	24	2
1963	4299	1406	576	173	86	10
1964	4782	1922	586	240	77	42
1965	4302	2343	842	200	74	21
1966	3925	2023	773	251	55	23
1967	2916	1817	573	180	70	8
1968	2506	1420	626	157	68	19
1969	4433	1213	533	234	46	22
1970	6136	2174	476	209	92	11
1971	8852	2926	987	168	86	42
1972	7992	3865	1077	412	59	36
1973	6059	3151	1305	339	151	19
1974	7853	2911	1153	425	96	49
1975	5426	3589	1301	297	105	20
1976	4099	2480	1192	496	76	18
1977	3433	1927	732	294	168	28
1978	1845	1558	679	155	76	59
1979	1748	867	498	217	28	31
1980	1945	723	248	139	60	6
1981	1448	838	271	59	38	17
1982	844	676	224	108	23	12
1983	1128*	362	198	34	27	4
1984	1645*	447	130	39	4	5
1985	611*	768	131	22	3	0
1986	468*	285	266	44	7	1

Table 3.4. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age classes 2-7, 1956-86.

Year	Age					
	2	3	4	5	6	7
1956	0.07	0.42	0.64	0.76	0.34	0.29
1957	0.17	0.65	1.25	1.45	0.80	0.44
1958	0.01	0.57	0.43	1.36	0.45	0.25
1959	0.01	0.27	0.98	0.79	1.32	0.65
1960	0.01	0.18	0.43	1.02	0.53	0.33
1961	0.01	0.06	0.24	0.66	0.59	0.65
1962	0.11	0.06	0.14	0.11	0.23	0.52
1963	0.11	0.18	0.19	0.12	0.04	0.32
1964	0.02	0.14	0.39	0.48	0.59	0.12
1965	0.06	0.42	0.52	0.60	0.50	0.40
1966	0.08	0.57	0.77	0.58	1.22	0.42
1967	0.03	0.38	0.60	0.28	0.60	0.80
1968	0.04	0.29	0.30	0.54	0.42	0.56
1969	0.02	0.24	0.25	0.25	0.71	0.51
1970	0.05	0.10	0.35	0.20	0.09	0.25
1971	0.14	0.31	0.18	0.36	0.19	0.21
1972	0.24	0.40	0.47	0.31	0.42	0.35
1973	0.04	0.32	0.43	0.57	0.43	0.56
1974	0.09	0.12	0.67	0.71	0.89	0.58
1975	0.09	0.41	0.28	0.67	1.07	0.80
1976	0.06	0.53	0.71	0.39	0.32	0.68
1977	0.10	0.35	0.87	0.67	0.35	0.65
1978	0.06	0.45	0.45	1.03	0.22	0.39
1979	0.19	0.56	0.59	0.60	0.89	0.27
1980	0.15	0.29	0.75	0.60	0.54	0.30
1981	0.07	0.63	0.23	0.23	0.43	0.49
1982	0.16	0.54	1.20	0.68	1.13	1.04
1983	0.24	0.34	0.94	1.38	1.08	0.34
1984	0.07	0.54	1.08	1.92	2.44	0.66
1985	0.07	0.37	0.39	0.41	0.63	1.22
1986	0.09	0.36	0.56	0.66	0.65	0.43

Table 3.5. Virtual population analysis estimates of annual exploitation rates for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), age classes 2-7, 1956-86.

	Age					
Year	2	3	4	5	6	7
1956	0.05	0.25	0.35	0.40	0.21	0.19
1957	0.11	0.36	0.55	0.60	0.41	0.26
1958	0.01	0.32	0.26	0.58	0.27	0.16
1959	0.01	0.17	0.47	0.41	0.57	0.36
1960	0.00	0.12	0.26	0.49	0.31	0.20
1961	0.00	0.04	0.16	0.36	0.33	0.36
1962	0.07	0.05	0.09	0.07	0.15	0.30
1963	0.08	0.12	0.12	0.09	0.02	0.20
1964	0.02	0.09	0.24	0.28	0.34	0.08
1965	0.04	0.25	0.30	0.34	0.29	0.24
1966	0.05	0.32	0.40	0.33	0.54	0.26
1967	0.02	0.23	0.34	0.18	0.34	0.42
1968	0.03	0.18	0.19	0.31	0.25	0.32
1969	0.02	0.16	0.16	0.16	0.38	0.30
1970	0.04	0.07	0.22	0.13	0.06	0.16
1971	0.09	0.19	0.12	0.23	0.13	0.14
1972	0.15	0.24	0.28	0.20	0.26	0.22
1973	0.03	0.20	0.26	0.33	0.26	0.32
1974	0.06	0.08	0.36	0.38	0.45	0.33
1975	0.06	0.25	0.18	0.36	0.50	0.42
1976	0.04	0.30	0.38	0.24	0.20	0.37
1977	0.07	0.22	0.44	0.36	0.22	0.36
1978	0.05	0.27	0.27	0.49	0.14	0.24
1979	0.13	0.32	0.33	0.34	0.45	0.18
1980	0.11	0.18	0.40	0.34	0.31	0.19
1981	0.05	0.35	0.15	0.15	0.26	0.29
1982	0.10	0.31	0.54	0.37	0.52	0.49
1983	0.15	0.21	0.46	0.59	0.50	0.21
1984	0.05	0.31	0.51	0.68	0.74	0.36
1985	0.05	0.23	0.24	0.25	0.35	0.55
1986	0.06	0.22	0.32	0.36	0.36	0.26

Table 3.6. Canada-U.S. annual landings (t), standardized equivalent effort (h) and number/h, by age, for Pacific cod from Queen Charlotte Sound (Areas 5A and 5B), 1956-86.

Year	C-US Land (t)	C-US Eff (h)	Age										
			1	2	3	4	5	6	7	8	9	10	11
1956	1753	8968	-	39.6	32.8	8.2	0.3	2.8	-	0.1	0.4	-	-
1957	2744	4125	5.6	169.0	90.9	27.9	4.7	1.1	0.2	0.2	0.3	-	-
1958	1178	18809	-	4.3	10.6	5.4	1.6	0.2	0.2	-	-	-	-
1959	946	3647	0.1	35.2	36.3	17.3	6.0	2.4	0.5	0.2	-	-	-
1960	618	4467	-	3.3	16.8	12.4	5.4	2.4	0.6	0.2	0.1	-	-
1961	240	3026	-	2.4	6.1	5.7	5.2	2.6	0.3	0.3	-	-	-
1962	422	4339	-	14.3	5.8	5.7	3.7	4.5	2.6	1.0	0.2	0.1	-
1963	677	7050	0.2	17.0	11.6	7.5	0.9	0.4	0.1	0.1	-	-	-
1964	1275	3773	-	77.1	28.8	10.4	5.1	1.8	0.3	-	-	-	-
1965	1940	3872	-	19.7	68.6	60.4	4.0	5.3	1.2	1.2	-	0.1	-
1966	1811	6385	0.2	45.0	28.5	14.2	8.0	2.1	0.9	0.3	0.1	-	-
1967	1501	8215	-	11.8	18.1	12.1	6.0	3.7	2.3	0.8	0.4	-	-
1968	960	6787	0.2	20.2	12.4	11.6	6.0	1.2	0.2	0.2	-	-	-
1969	699	8064	0.2	7.7	8.6	8.0	2.1	1.8	0.7	0.4	0.1	-	-
1970	299	10969	-	5.4	3.9	1.2	0.4	0.1	0.1	-	-	-	-
1971	928	11204	0.4	17.3	3.5	2.2	2.4	1.5	1.0	0.2	0.1	-	0.1
1972	2320	11079	0.1	75.9	18.5	6.1	0.6	0.1	-	-	-	-	-
1973	1914	8404	0.2	12.2	24.5	40.5	1.0	0.6	2.3	-	-	0.6	-
1974	2292	10048	-	29.4	24.6	9.7	8.1	3.3	0.6	-	-	-	-
1975	2444	8386	0.3	68.6	41.6	13.3	4.9	0.4	1.2	-	0.2	-	-
1976	2271	9681	0.8	57.2	49.5	9.1	2.2	0.3	0.5	-	0.4	-	-
1977	1268	8100	0.9	65.8	22.9	6.3	2.2	0.7	0.4	0.3	-	-	-
1978	1959	6929	0.8	29.6	70.6	15.1	2.4	2.4	0.4	0.1	-	0.1	-
1979	1904	7163	1.0	79.3	19.1	12.1	5.6	-	0.4	-	-	-	-
1980	1335	6003	1.0	65.5	32.0	8.3	1.4	0.8	0.1	-	-	0.1	-
1981	858	4595	1.6	42.4	21.5	9.0	2.1	1.0	0.5	0.2	0.1	0.1	-
1982	603	4709	-	21.0	24.5	10.3	1.2	1.1	0.1	0.1	-	-	-
1983	183	5722	-	3.9	6.6	1.6	0.2	0.1	0.1	-	-	-	-
1984	382	5096	0.2	13.0	8.7	4.1	1.0	0.5	0.2	0.1	-	-	-
1985	299	7057	-	4.0	10.6	5.7	0.4	0.3	0.2	-	-	-	-
1986	241	7191	-	8.0	5.1	4.6	1.4	0.1	0.1	-	-	-	-

Table 3.7. Canada-U.S. annual landings (t), standardized equivalent effort (h) and number/h, by age, for Pacific cod from Hecate Strait (Areas 5C+5D), 1961-86.

Year	C-US Land (t)	C-US Eff (h)	C-US LPUE (kg/h)	Age									
				1	2	3	4	5	6	7	8	9	10
1961	1616	4391	368	-	21.5	140.6	60.5	11.2	2.0	1.1	1.1	-	-
1962	1690	2735	618	2.0	101.9	153.6	87.9	40.7	16.1	4.8	1.5	1.2	-
1963	2927	3157	927	14.7	170.8	378.7	190.4	60.0	10.4	12.0	3.8	1.6	0.1
1964	5228	3050	1714	1.9	469.9	290.9	122.9	52.8	9.4	1.6	0.5	0.3	-
1965	9119	5500	1658	0.5	58.3	425.2	178.8	39.1	10.9	0.8	0.9	0.1	-
1966	9519	6671	1427	1.1	66.1	228.9	167.9	46.4	11.9	1.6	0.2	0.1	0.1
1967	5112	4755	1075	-	200.1	142.7	86.7	38.4	14.3	4.6	1.3	0.2	0.1
1968	5165	14074	367	0.3	8.1	109.3	27.8	13.5	6.4	1.6	0.5	0.3	-
1969	2959	12078	245	0.2	36.7	24.4	35.0	13.2	3.4	1.8	0.2	0.1	0.1
1970	1339	8868	151	-	15.1	45.1	14.2	3.1	1.9	0.7	0.3	-	0.2
1971	1474	6856	215	0.8	70.4	24.0	15.7	7.9	1.1	0.7	0.5	-	-
1972	2694	4177	645	0.5	238.7	81.9	45.5	14.3	2.4	2.0	0.4	0.9	-
1973	4003	3552	1127	7.4	206.9	239.0	81.6	19.3	10.9	1.9	0.5	0.6	0.2
1974	4764	4630	1029	0.5	250.1	100.4	80.4	26.3	6.9	1.0	0.6	0.5	-
1975	4982	8649	576	0.1	68.3	107.0	42.1	21.6	2.6	4.2	1.7	0.8	0.1
1976	5016	10582	474	0.2	47.1	106.3	29.1	10.4	4.1	1.9	0.2	0.3	-
1977	3523	10124	348	0.1	93.3	54.3	27.3	5.1	3.2	1.0	-	-	-
1978	2102	5904	356	3.6	13.5	76.8	37.1	10.9	1.6	1.2	0.3	-	-
1979	4695	10274	457	0.7	133.6	34.1	44.6	10.5	3.3	0.6	0.3	-	0.1
1980	4540	12473	364	0.5	54.6	75.2	31.1	7.8	2.7	1.0	0.2	0.1	-
1981	3182	15752	202	0.9	26.0	28.2	28.1	9.9	1.4	0.9	-	-	-
1982	2077	5409	384	0.7	41.4	72.4	32.9	10.2	2.9	0.6	0.2	0.2	-
1983	2717	6967	390	0.3	32.9	63.3	37.4	12.8	3.0	0.9	0.2	-	-
1984	1748	5378	325	-	69.3	48.0	33.4	10.6	4.3	0.4	0.4	-	-
1985	1064	7093	150	0.4	10.7	30.9	10.6	3.7	1.9	0.2	0.1	-	-
1986	2099	3873	542	2.2	21.2	46.7	83.1	15.5	7.5	0.9	0.6	-	-

Table 3.8. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from Hecate Strait (Areas 5C and 5D), for age classes 2-7, 1956-86. (Asterisks indicate estimates of age-2 numbers at age considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope (1972).)

Year	Age					
	2	3	4	5	6	7
1961	6822	2636	964	1002	188	23
1962	9967	3631	989	334	508	96
1963	11689	5228	1667	368	104	245
1964	16285	5957	1983	479	69	33
1965	8309	7778	2595	808	147	17
1966	5717	4280	2565	717	285	37
1967	7945	2793	1258	612	173	98
1968	2827	3631	1040	394	202	46
1969	3525	1450	901	292	82	47
1970	4628	1597	579	196	50	16
1971	5093	2411	583	223	87	15
1972	7621	2418	1194	241	83	42
1973	5598	3432	1070	513	88	38
1974	5943	2520	1267	377	229	21
1975	6301	2393	1040	426	118	102
1976	4922	2992	650	309	101	48
1977	5709	2313	831	139	91	25
1978	4539	2435	860	258	40	27
1979	6863	2398	996	311	94	15
1980	3900	2748	1055	224	93	27
1981	3711	1634	827	303	54	26
1982	3339*	1723	573	146	57	14
1983	2322*	1654	655	185	41	20
1984	4273*	1101	583	172	38	8
1985	1465*	2049	413	190	53	5
1986	862*	741	958	171	85	20

Table 3.9. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from Hecate Strait (Areas 5C and 5D), for age classes 2-7, 1956-86.

	Age					
Year	2	3	4	5	6	7
1961	0.02	0.37	0.45	0.07	0.06	0.32
1962	0.04	0.17	0.38	0.56	0.12	0.20
1963	0.06	0.36	0.64	1.07	0.53	0.23
1964	0.13	0.22	0.29	0.58	0.78	0.22
1965	0.05	0.50	0.68	0.43	0.76	0.40
1966	0.11	0.61	0.82	0.81	0.45	0.48
1967	0.17	0.38	0.55	0.50	0.71	0.34
1968	0.06	0.78	0.66	0.96	0.86	1.02
1969	0.18	0.31	0.92	1.16	1.02	0.87
1970	0.04	0.40	0.34	0.20	0.56	0.64
1971	0.13	0.09	0.27	0.38	0.12	0.50
1972	0.19	0.21	0.24	0.39	0.17	0.30
1973	0.19	0.39	0.43	0.19	0.83	0.26
1974	0.30	0.27	0.48	0.55	0.20	0.33
1975	0.13	0.69	0.61	0.83	0.29	0.63
1976	0.14	0.67	0.93	0.61	0.79	0.77
1977	0.24	0.38	0.56	0.64	0.62	0.73
1978	0.03	0.28	0.41	0.40	0.39	0.43
1979	0.31	0.21	0.88	0.60	0.64	0.74
1980	0.26	0.59	0.64	0.82	0.65	0.90
1981	0.16	0.44	1.12	1.06	0.73	1.14
1982	0.09	0.36	0.52	0.66	0.44	0.39
1983	0.14	0.43	0.73	0.96	1.05	0.50
1984	0.13	0.37	0.51	0.56	1.40	0.39
1985	0.07	0.15	0.27	0.19	0.39	0.51
1986	0.13	0.39	0.57	0.61	0.58	0.28

Table 3.10. Virtual population analysis estimates of annual exploitation rate for Pacific cod from Hecate Strait (Areas 5C and 5D), for age classes 2-7, 1956-86.

	Age					
Year	2	3	4	5	6	7
1961	0.01	0.23	0.28	0.05	0.05	0.21
1962	0.03	0.12	0.24	0.33	0.09	0.14
1963	0.05	0.23	0.36	0.51	0.32	0.15
1964	0.09	0.15	0.19	0.34	0.42	0.15
1965	0.04	0.30	0.38	0.27	0.41	0.25
1966	0.08	0.36	0.44	0.43	0.28	0.29
1967	0.12	0.24	0.33	0.30	0.39	0.22
1968	0.04	0.42	0.38	0.48	0.45	0.50
1969	0.13	0.20	0.47	0.55	0.50	0.46
1970	0.03	0.25	0.22	0.14	0.33	0.37
1971	0.09	0.07	0.18	0.24	0.09	0.30
1972	0.13	0.14	0.16	0.25	0.12	0.20
1973	0.13	0.25	0.27	0.13	0.44	0.17
1974	0.19	0.18	0.29	0.32	0.14	0.22
1975	0.09	0.39	0.35	0.44	0.19	0.36
1976	0.10	0.38	0.47	0.36	0.43	0.42
1977	0.17	0.24	0.33	0.37	0.36	0.40
1978	0.02	0.19	0.25	0.25	0.24	0.27
1979	0.20	0.15	0.46	0.35	0.36	0.41
1980	0.17	0.34	0.37	0.43	0.37	0.47
1981	0.11	0.27	0.54	0.52	0.41	0.54
1982	0.07	0.23	0.31	0.38	0.27	0.25
1983	0.10	0.27	0.40	0.48	0.52	0.30
1984	0.09	0.23	0.31	0.33	0.61	0.25
1985	0.05	0.11	0.18	0.14	0.25	0.31
1986	0.10	0.24	0.34	0.35	0.34	0.19

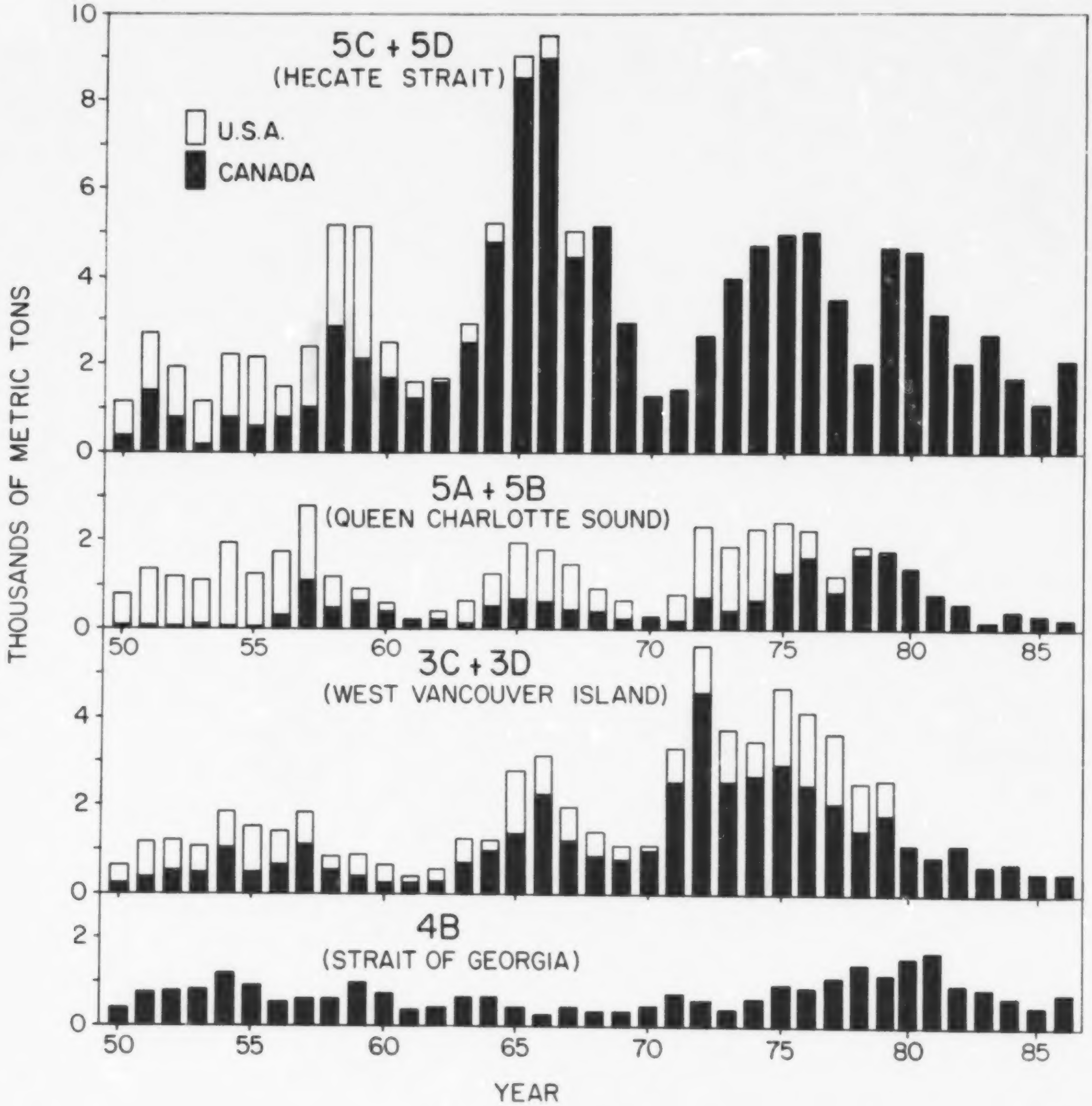

Fig. 3.1. Canada-U.S. annual landings (t) of Pacific cod, by region. 1950-86.

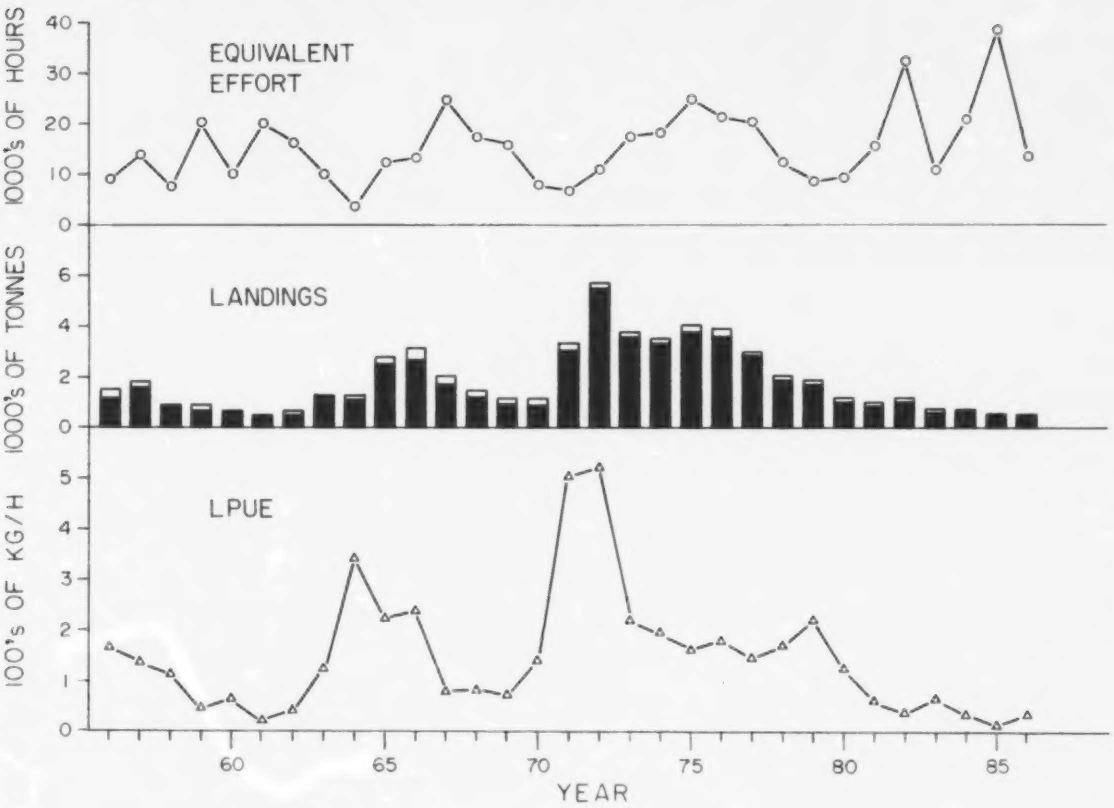

Fig. 3.2. Standardized Canada-U.S. landing statistics for Pacific cod from the west coast of Vancouver Island, 1956-86. Shaded portion of column from 3c, clear portion from 3d.

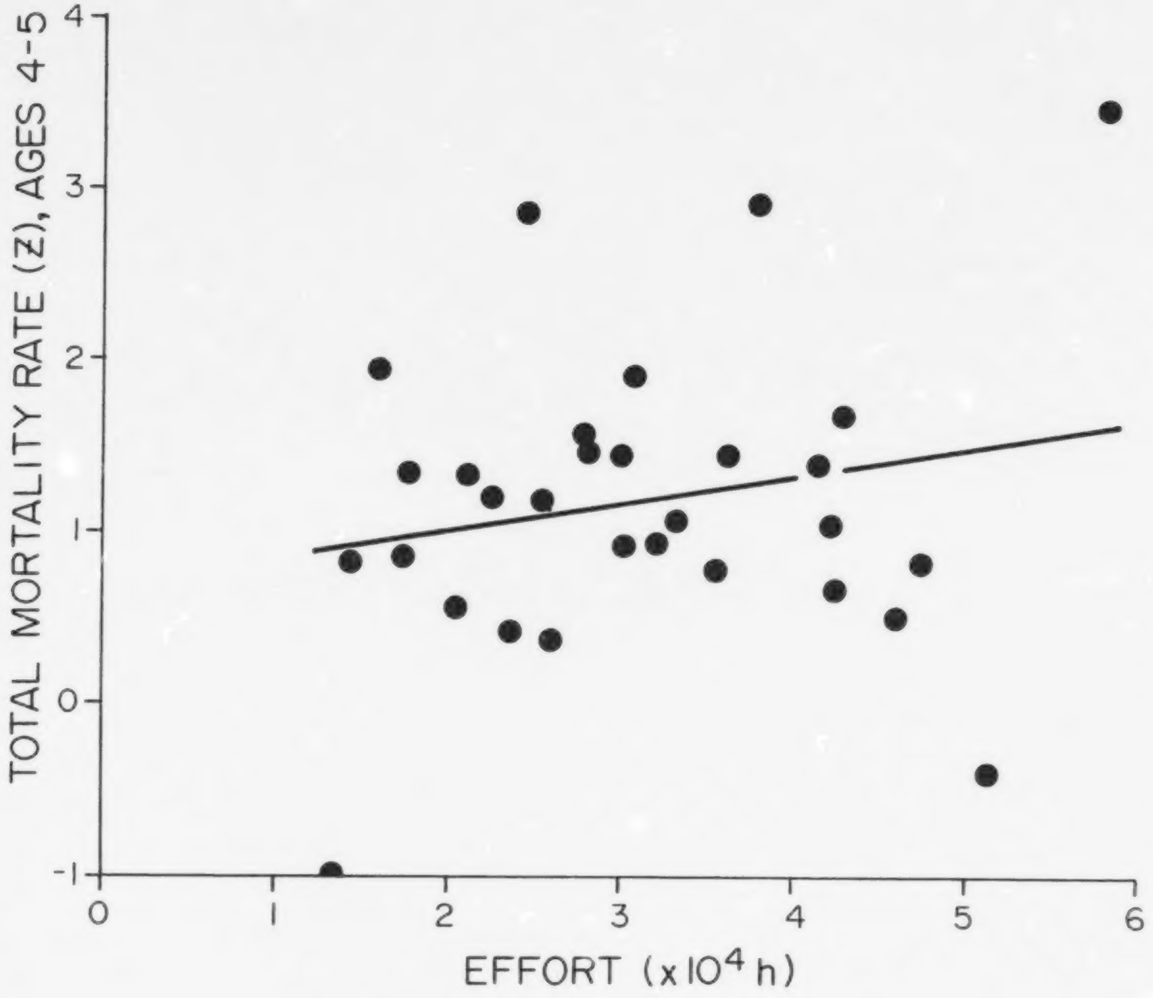

Fig. 3.3. Total mortality rate (Z) for ages 4-5 vs corresponding effort for Pacific cod from the west coast of Vancouver Island, 1956-86.

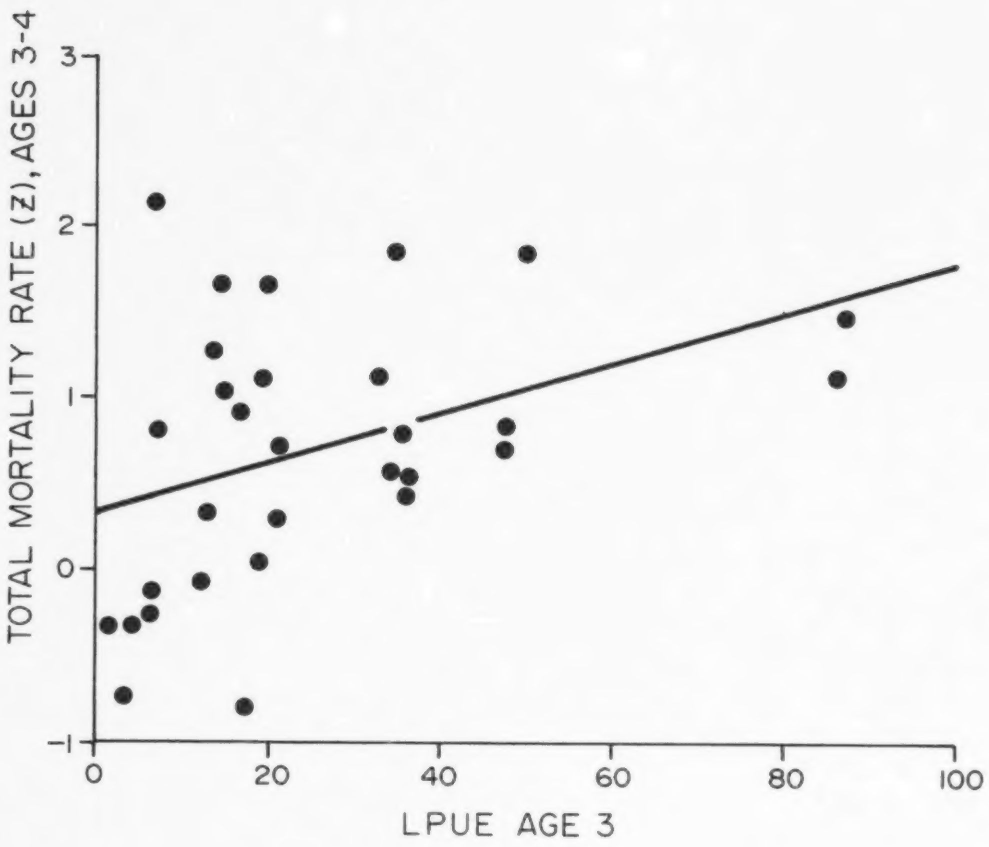

Fig. 3.4. Total mortality rate (Z) for ages 3-4 vs year-class strength (LPUE at age 3) for Pacific cod from the west coast of Vancouver Island, 1953-82 year-classes.

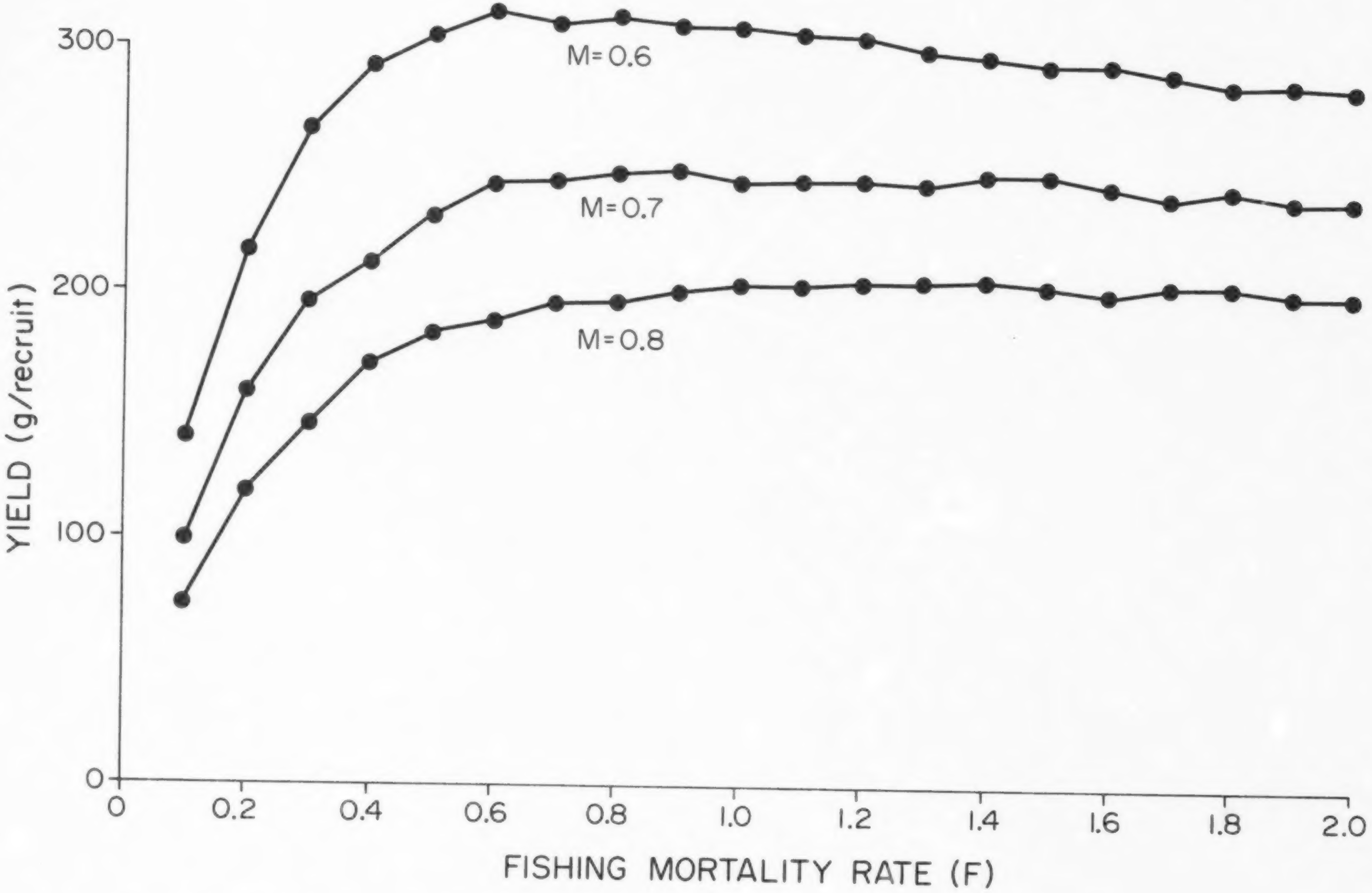

Fig. 3.5. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island at three levels of M (0.6, 0.7 and 0.8), mesh size = 5.3", and minimum commercial size = 41 cm.

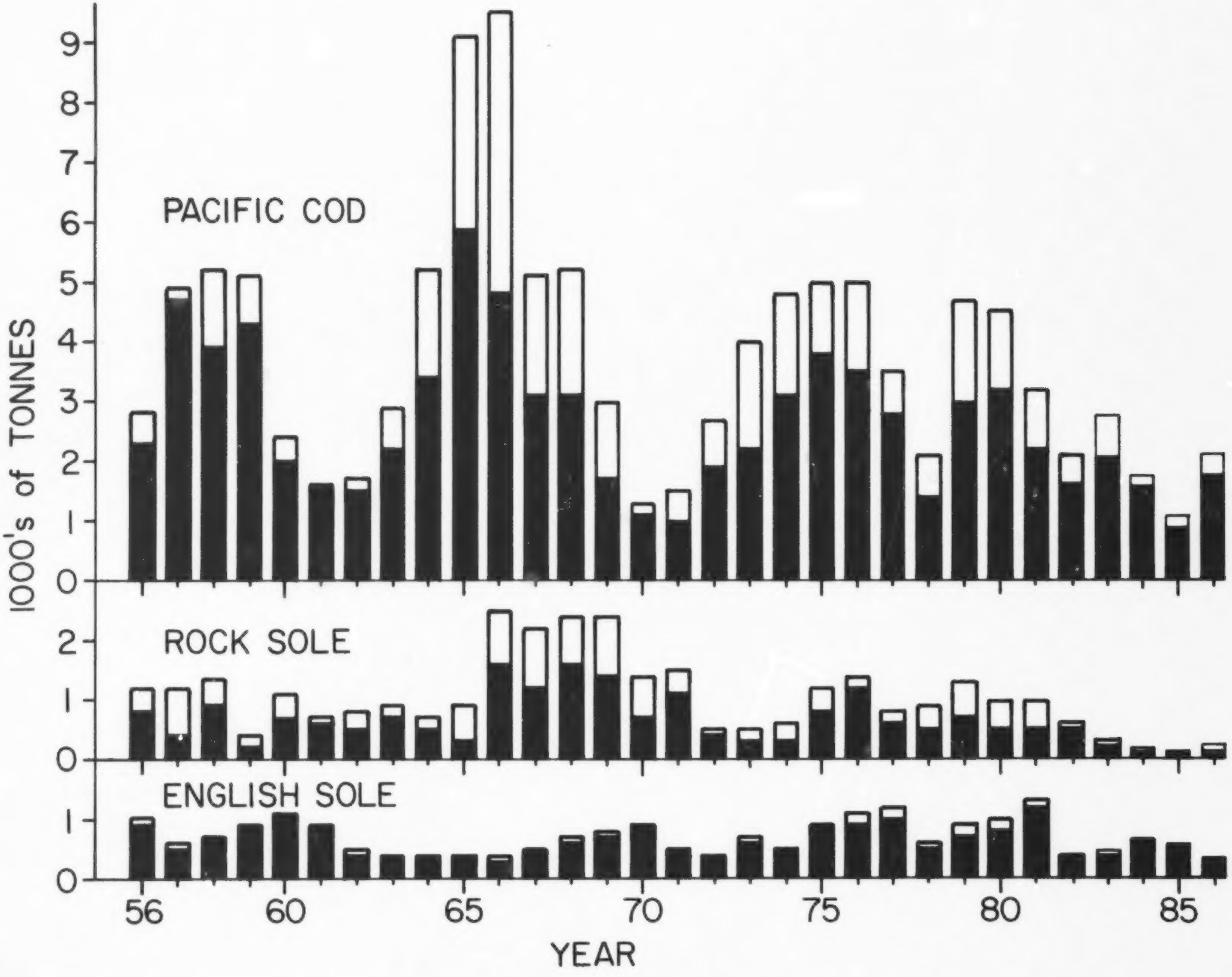

Fig. 3.6. Canada-U.S. annual landings (t) of Pacific cod, rock sole and English sole from Hecate Strait, 1956-86. (Shaded areas = landings from Area 5D.)

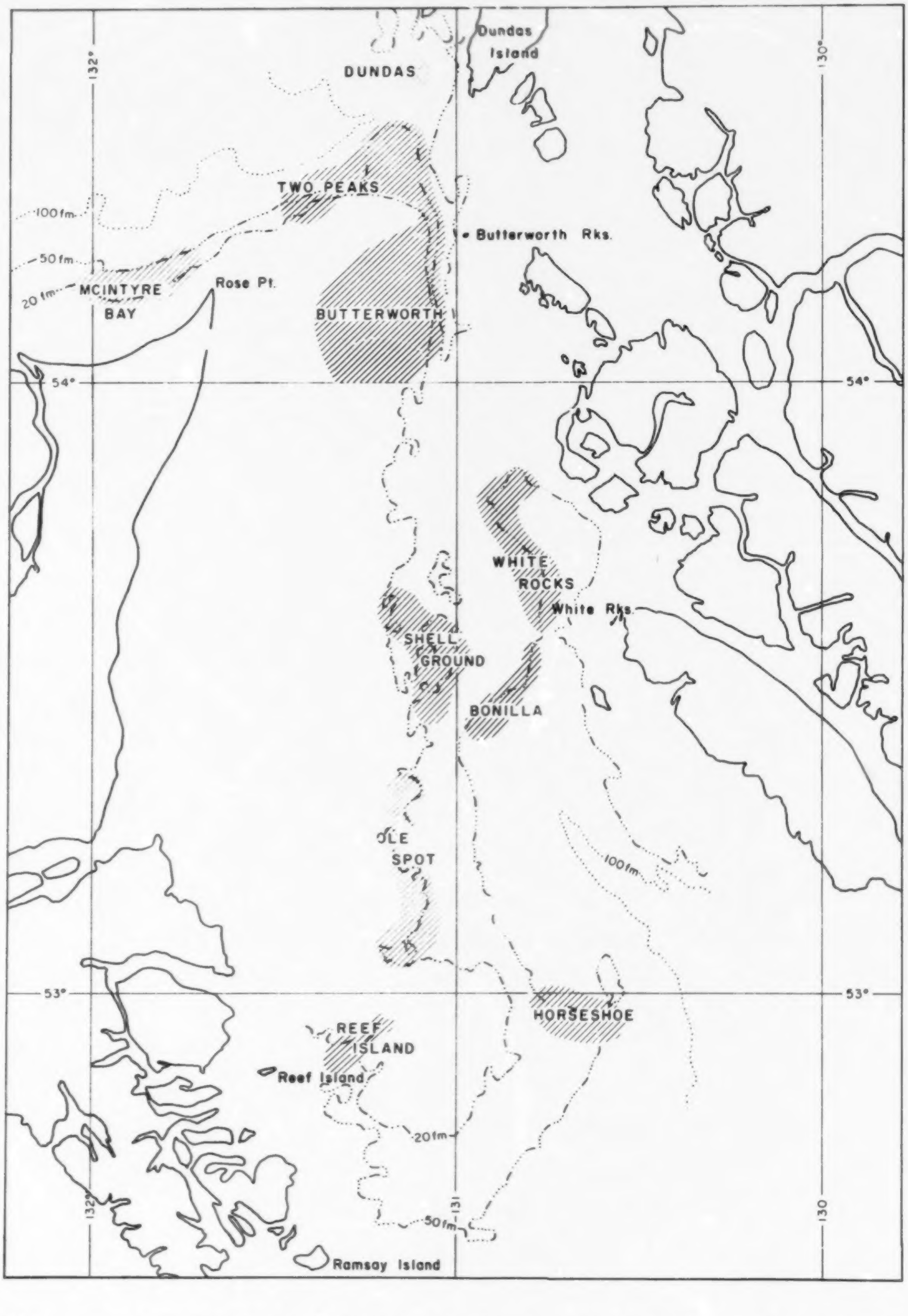
Dundas Island
DUNDAS
TWO PEAKS
Butterworth Rks.
100 fm
50 fm
20 fm
MCINTYRE BAY
Rose Pt.
BUTTERWORTH
132°
130°
54°
53°
131
WHITE ROCKS
White Rks.
SHELL GROUND
BONILLA
OLE SPOT
100 fm
HORSESHOE
REEF ISLAND
Reef Island
20 fm
50 fm
Ramsay Island

Fig. 3.7. Important trawling grounds for Pacific cod in Hecate Strait.

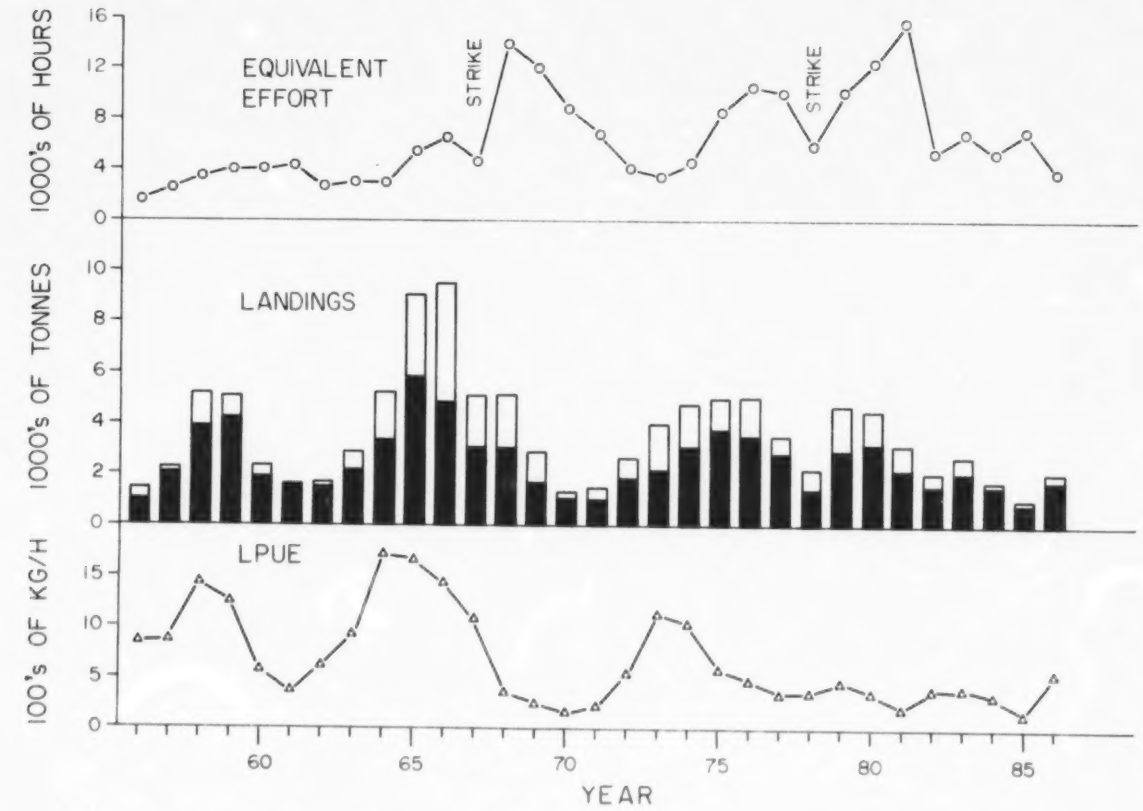

Fig. 3.8. Standardized Canada-U.S. landing statistics for Pacific cod from Hecate Strait, 1956-86. Shaded portion of column from Area 5D; clear portion from 5C.

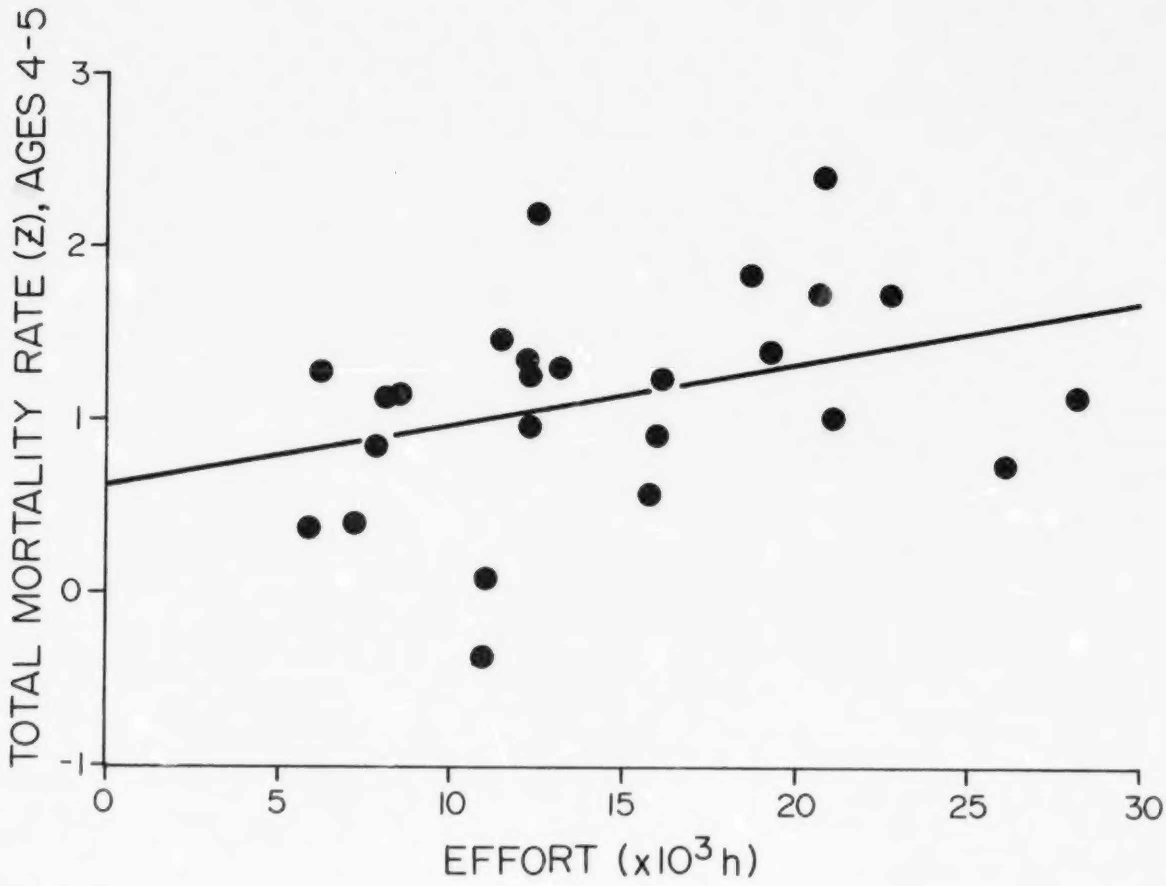

Fig. 3.9. Total mortality rate (Z) for ages 4-5 vs corresponding effort (h) for Pacific cod from Hecate Strait, 1956-86.

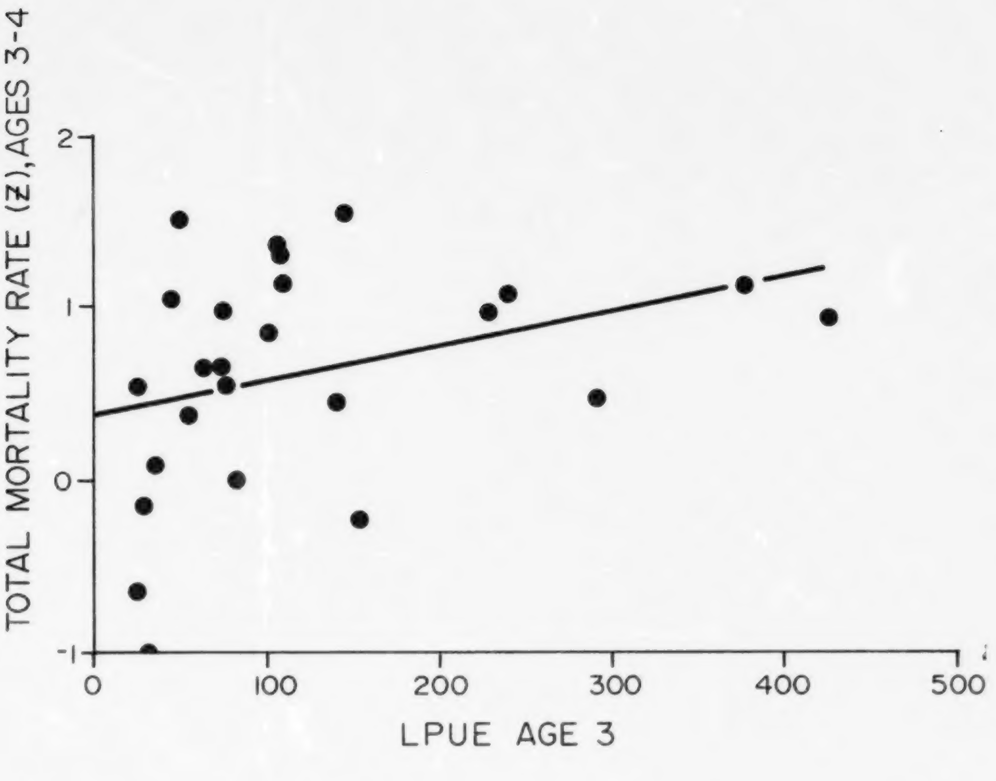

Fig. 3.10. Total mortality rate (Z) for ages 3-4 vs year-class strength (LPUE at age 3) for Pacific cod from Hecate Strait, 1958-82 year-classes.

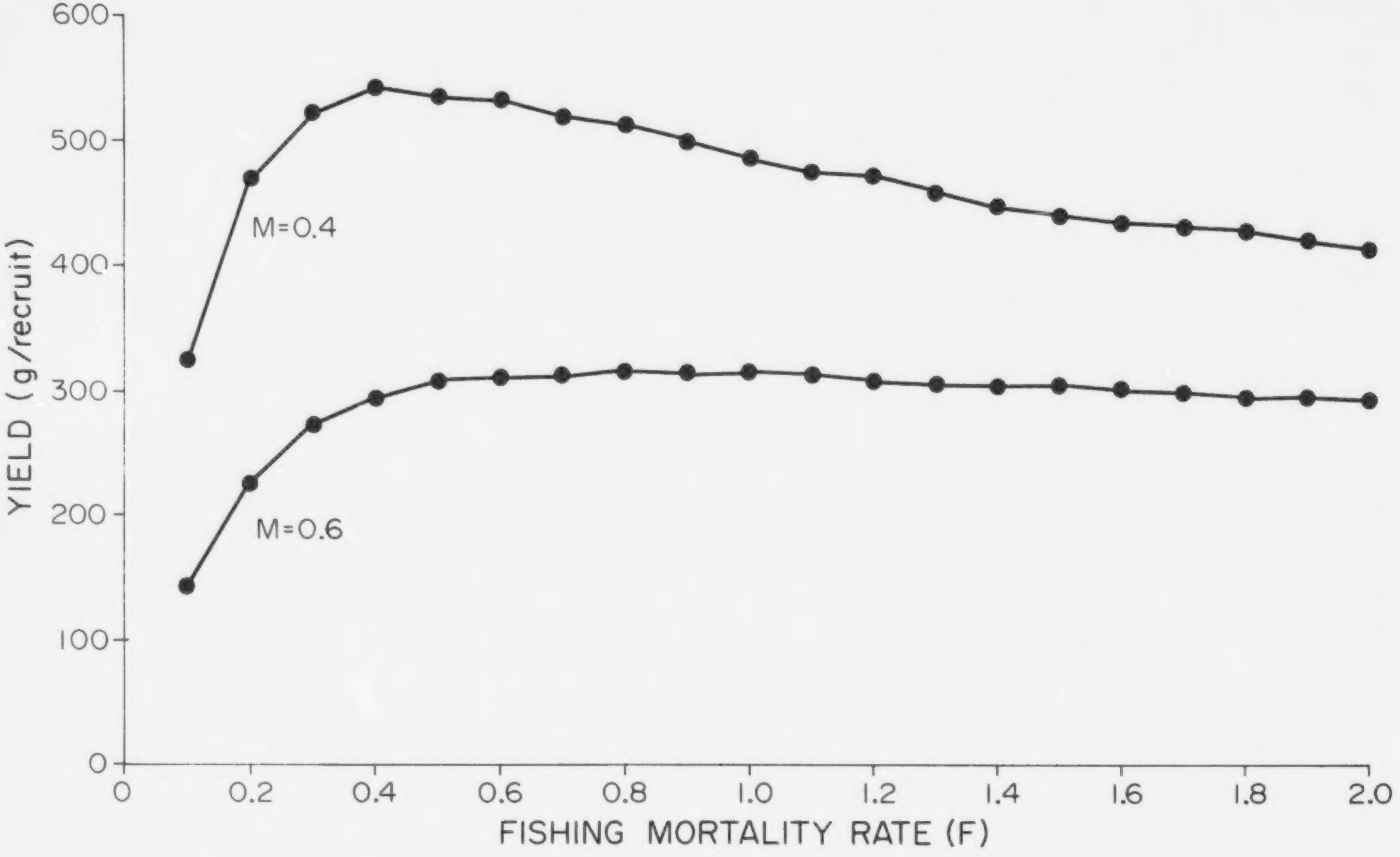

Fig. 3.11. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from Hecate Strait at two levels of M (0.4 and 0.6), mesh size = 5.3", and minimum commercial size = 41 cm.

4.0. FLATFISH

by J. Fargo

4.1. Coastwide

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. Strait of Georgia

Yield options are not proposed for flatfish for this region.

4.3. West Coast of Vancouver Island

Yield options are not proposed for flatfish for this region.

4.3.1. Petrale sole

4.3.1.1. Introduction

The petrale sole (Eopsetta jordani) population off the west coast of Vancouver Island is thought to be composed of two stocks on the basis of tagging experiments conducted in the 1960s (Ketchen and Forrester 1966). The "northern" stock occupies Areas 3D, 5A, 5B, 5C, and 5D while the "southern" stock occupies both the Canadian and U.S. portions of Area 3C.

Ketchen and Forrester (1966) showed a relationship between petrale sole year-class production and ocean temperature at the time of spawning. High temperatures (7.5-9.5°C) had a positive effect on petrale sole year-class production while lower temperatures (5.0-7.0°C) had a negative effect. Follow-up studies by Pedersen (1975) supported the analysis of Ketchen and Forrester, which suggested that fishery effects on this species appeared to be overshadowed by environmentally induced variations in the production of year-classes.

In recent years, management has invoked a trip limit regulation (which was originally proposed by industry) on petrale sole because of a continued decline in abundance for the species. The intent of the regulation is to allow retention and landing of incidental catches of petrale sole in fisheries off the west coast of Vancouver Island while discouraging a target fishery for the species while the stocks are at low levels of abundance.

4.3.1.2. Landing statistics

An increase in recruitment, presumably due to favourable environmental conditions, contributed to peak landings for the "southern" stock (Ketchen and Forrester 1966) in the 1940s and early 1960s (Table 4.1). The most recent recruitment surge for this stock took place from 1970-75. From 1976-86 the mean annual landings for the "southern" stock are 381 t with an overall decline in landings over this period. Landings for 1986 were 272 t. Landings for the "northern" stock averaged 155 t for the period 1976-86, while landings for 1986 were 169 t (Table 4.2). An overall trend in landings for the "northern" stock from 1976-86 cannot be distinguished. A lack of effort data from the U.S. fishery for petrale sole makes it impossible to construct an accurate LPUE time series for the species.

4.3.1.3. General biological information

A time series of length frequency anomalies has been produced from port samples of length frequency data for the "southern" stock of petrale sole for the period 1966-86 (Fig. 4.1). The anomalies represent the deviation from the long-term mean of the numbers of fish in each centimeter interval for each year. Samples are standardized to represent 1000 fish prior to computing the deviations at each centimeter interval to compensate for unequal sample sizes. Clear areas in the anomalies represent above average numbers of fish present while shaded areas represent below average numbers of fish present. A succession of clear areas moving from left to right over a series of consecutive years represents the contribution of a particular year-class. According to the anomalies, the last major recruitment surge took place from 1970-75, a period when landings for the "southern" stock also increased significantly. Since 1975 there has been a series of years of poor recruitment. A series of anomalies for the "northern" stock has not been produced yet but examination of length frequencies of port samples for the stock show that landings are predominantly made up of larger (older) fish.

4.3.1.4. Condition of the stock

All indications are that petrale sole stocks off the west coast of Vancouver Island are at low levels of abundance with recruitment also at low levels. Warm water temperatures (8-9°C) at time of spawning, which are favourable to petrale sole year-class production (Ketchen and Forrester 1966; Fargo 1985) were prevalent in the early 1980s but have not, as yet, resulted in a significant increase in recruitment for petrale sole stocks off the west coast of Vancouver Island. The reason for this could be that a minimum size spawning stock is necessary for successful year-class production even under favourable environmental conditions, and the current stock size of petrale sole may be below this level. The minimum stock size concept has been demonstrated for rock sole in Hecate Strait (Fargo 1985). Signs of increasing recruitment as a result of favourable ocean temperatures should have been noticed by the 1986 fishery because age of recruitment for petrale sole is 4 years.

4.3.1.5. Yield options

A 44,000 lb trip limit regulation for petrale sole from January 1-March 31 is in effect, coastwide. The January-March period corresponds to the spawning time for petrale sole, a period when these stocks are particularly vulnerable to exploitation. This regulation is the result of a request by industry aimed at reducing a target fishery on petrale sole while stocks are depressed. Table 4.3. shows the coastwide Canadian landings of petrale sole from January 1-March 31 for the past 17 years by trip category. For the last 3 years, no landings of petrale sole have exceeded 25,000 lb. during this 3-month period.

(1) Conservative sustainable option: Analysis shows that petrale sole stocks are depressed compared to 1950s and 1960s levels and that recruitment could be impaired. A target fishery for petrale sole should be discouraged. A trip limit of 25,000 lb should be adequate to allow fishermen to retain incidental catches of petrale sole.

(2) Risk sustainable option: Previous analyses have all indicated that petrale sole stock size has no bearing on year-class production for the

species and the trip limit should be removed. As a caveat to this option, all previous analyses concerning stock and recruitment for the species were conducted when petrale sole stocks were at significantly higher levels of abundance than they are at present.

4.4. Queen Charlotte Sound

4.4.1. Rock sole

4.4.1.1. Introduction to Area 5A

The rock sole (Lepidopsetta bilineata) is a minor component of the shelf, on-bottom trawl fishery in Area 5A. Other principal members of this multispecies fishery are Pacific cod (Gadus macrocephalus) and lingcod (Ophiodon elongatus). Rock sole are caught in the 40-50 fathom depths of Cook Bank.

4.4.1.2. The fishery

The multispecies fishery in Queen Charlotte Sound has been dominated traditionally by Pacific cod and, in recent years, by lingcod. Most catches of rock sole are taken incidentally to these other species, but it is taken as a target species on occasion.

4.4.1.3. Landing statistics

Landing statistics were standardized using the method of Westrheim and Foucher (1985b). Basically, the standardization was a linear function of LPUE on vessel horsepower.

Once effort was standarized, allocation of effort followed the procedure outlined for multispecies fisheries by Westrheim (1983). That is, each species in each area/time cell (in this case rock sole in Area 5A) was allocated the standardized all-species effort expended in the depth intervals containing the rank-1 (most) and rank-2 (next-most) landings of that species. This is hereafter referred to as the "option-2" method.

LPUE for rock sole in Area 5A has declined from 117 kg/h in 1984 to 76 kg/h in 1985 and 13 kg/h in 1986 (Table 4.4).

A major source of variation in LPUE for minor species, such as rock sole, in multispecies fisheries, comes from combining incidental catch data for the species with direct catch data (i.e. data where the species was the object of directed fishing effort). The proportion of incidental catches varies among years. In recent years, the trip limit regulation for rock sole has probably compounded this problem by discouraging a directed fishery for rock sole.

The majority of fishing effort expended in Area 5A in 1986 came as a result of an intensive fishery for lingcod at depths of 50-60 fathoms, deeper than the normal depth of capture for rock sole. For this reason the rock sole LPUE calculated in Table 4.4 for 1986 is almost certainly too low. The 1986 LPUE calculated for 5A rock sole using catches and effort from the 40-50 fathom depth range is similar to the 1985 LPUE estimate.

4.4.1.4. Condition of the stock

On the basis of trends in LPUE, the Area 5A rock sole stock is considered to be at average to low levels of abundance with recruitment at low levels, although length frequency samples, used for monitoring recruitment, were not obtained in 1986. Average yield for the stock at similar levels in the past (1972-78), based on LPUE trends, was approximately 100 t.

4.4.1.5. Yield options

Sustainable Yield option: A yield of 100 t is considered to be sustainable for the current stock level and low recruitment mode. The 30,000 lb trip limit regulation is consistent with this option.

Non-sustainable Yield option: A free fishery at this time could reduce the 5A stock to a lower level than has been observed in the past and the possibility of recruitment overfishing would be increased.

4.4.1.6. Introduction to Area 5B

Rock sole is a minor component of the shelf, on-bottom trawl fishery in Area 5B. Pacific cod and lingcod are the major species in this multispecies fishery.

4.4.1.7. The fishery

Catches of rock sole in Area 5B have traditionally come from the 40-50 fathom depth range on the outer edges of Goose Island Bank, which is considered to have good "trawlable" bottom. There has been speculation among fishermen over the years that rock sole also occupy the top of the bank (the shallower depths) which is composed of rough bottom type, not amenable to trawl capture of flatfish. Rock sole in Hecate Strait are most abundant at 10-30 fathom depths.

4.4.1.8. Landing statistics

Problems with interpretation and derivation of landing statistics for rock sole in Area 5B are the same as those discussed in Section 4.4.1.3. LPUE for 1986 was 52 kg/h and was consistent with the trend established over the period 1973-85 (Table 4.5). As in the case of Area 5A rock sole, the 1986 LPUE estimate Area 5B for rock sole is considered to be biased low because most of the rock sole was caught incidentally in the intensive fishery for lingcod. This effort is expended mainly at depths deeper than those at which rock sole have normally been taken on Goose Island Bank.

4.4.1.9. General biological information

Length frequency samples from Area 5B rock sole in 1986 have been analyzed and a significant increase in younger (smaller size) rock sole was noted in the 1986 fishery. It is too early to tell if this is an indication of an increase in recruitment for the stock, but an increase in yield and LPUE would be expected over the next few years if this is the case.

4.4.1.10. Condition of the stock

On the basis of LPUE trends, the Area 5B stock has been at a stable level of abundance since the early 1970s. The average yield over this time period has been approximately 250 t. An increase in recruitment could increase that figure significantly over the next few years.

4.4.1.11. Yield options

Low risk sustainable Yield option: A yield of 250 t is considered to be sustainable for the Area 5B stock. The 30,000 lb trip limit currently in effect for Queen Charlotte Sound is consistent with this option.

High risk sustainable option: Yields of 400 t could be sustained with a significant increase in recruitment. Free fishing should be permitted to take advantage of this. As a caveat to this option, no trend in recruitment has yet been demonstrated. Only one year's observation is used to describe a possible increase in recruitment (increase in percentage of smaller size fish). This phenomenon could also be due to sample bias or error.

4.5. Hecate Strait

4.5.1. Rock sole

4.5.1.1. General Introduction

The rock sole (Lepidopsetta bilineata) is one component in a multi-species on-bottom trawl fishery in Hecate Strait along with English sole (Parophrys vetulus) and Pacific cod (Gadus macrocephalus). Two stocks of rock sole have been identified using abundance trends in landing statistics, length-frequency anomalies and results of a 1982 tagging experiment (Fargo and Westrheim 1987).

4.5.1.2. Introduction to Area 5C

The fishery for rock sole in Area 5C is seasonal. The majority (84%) of the landings occur during April-September. The spring (April-May) fishery is predominantly on a spawning population at Reef Island-Cumshewa grounds while summer and fall landings come mainly from the multispecies fisheries at Horseshoe and Ole Spot grounds. The rock sole fishery in Area 5C was curtailed during 1980-83 due to an area closure (Reef Island-Cumshewa) imposed for conservation reasons. Landing statistics and length frequency anomalies are the basis for this assessment.

4.5.1.3. Landing statistics

A description of the method used for deriving the landing statistics used in this assessment is contained in Section 4.4.1.3. LPUE for rock sole in Area 5C rose in 1986 to 131 kg/h, up 49% from 1985. Effort increased over 100% from 1985 to 656 hours (Table 4.6; Fig. 4.2). LPUE has shown an increasing trend in recent years but it is still below the average for the last 10 years. Detailed examination of the landing statistics show that LPUE for the last three years is based on only about 10% of the number of catch/effort observations for previous years. This increases the amount of uncertainty in the LPUE index (Stanley, in prep.).

4.5.1.4. General biological information

Length frequency data has now been compiled in numbers per hour and a time series of length frequency anomalies (see section 4.3.1.3) in numbers per hour has been produced for the period 1966-86 (Fig. 4.3). Anomalies computed in numbers per hour facilitate comparison of recruitment among years. The anomaly for 1986 indicates that recruitment is currently low compared to previous years. There has been no significant increase in recruitment for the stock since the late 1970s, however, a look at samples collected thus far in 1987 indicates that the number of smaller rock sole (recruits) in the landings is increasing.

4.5.1.5. Condition of the stock

The Area 5C rock sole stock is considered to be at low levels, with recruitment currently at low levels. This is based on trends in LPUE and length frequency anomalies.

4.5.1.6. Yield options

Sustainable yield option -- The sustainable yield as indicated by trend in LPUE from 1980-86 is between 100-400 t for the Area 5C stock. A yield of 100 t would constitute a low risk for the stock while a yield of 400 t would constitute a high risk. A trip limit of 30,000 lb is consistent with a non-directed fishery for this stock and is consistent with the sustainable yield option.

Non-sustainable option -- A free fishery would allow a directed fishery rock sole to take place in Area 5C. This option may not be consistent with sustainable yield for this stock at the present time due to the low recruitment mode.

4.5.1.7. Introduction to Area 5D

The rock sole population in Area 5D is one of the most intensively studied marine fish populations in British Columbia (Forrester and Thomson 1969; Stocker 1981; Fargo 1985). For the past 30 years the stock has been characterized by cyclic abundance trends attributed to major surges in recruitment about once a decade. A long-term decline in abundance over this time period has also been apparent for the stock. Ocean temperature at the time of spawning has been shown to be an important determinant of year-class production for the stock (Fargo 1985).

Results from recent tagging experiments have demonstrated a significant increase in the natural mortality rate for the species in recent years (Fargo and Westrheim 1987).

4.5.1.8. The fishery

The fishery for rock sole in Area 5D is mainly a seasonal one. The majority (80%) of the landings occur during the months April-September. Principal grounds are Two Peaks and Butterworth. Rock sole is the target species in the shallow (10-19 fath) depths and is taken incidentally to Pacific cod at depths greater than 40 fathoms.

4.5.1.9. Landing statistics

The difficulty in interpreting landing statistics for rock sole has already been discussed in Section 4.4.1.3. Past analysis (Fargo 1985) has shown that 50% of the variation in rock sole LPUE in Area 5D can be accounted for by fishing effort directed at Pacific cod, the major target species in Hecate Strait.

Two different methods have been used to standardize landing statistics (1956-86) for rock sole in Area 5D (Table 4.7; Fig. 4.4). The first method is described in Section 4.4.1.3. The second method involved the use of a log linear model similar to those of Gavaris (1980) and Kimura (1981). Independent variables included in the model were vessel horsepower, and depth. The model was applied to a 25% qualified data set for rock sole in Area 5D (the rock sole catch must be greater than or equal to 25% of the total catch for a given landing). The 25% qualification level was used to reduce the amount of variability in the catch/effort data caused by "incidental" catches of rock sole. This second standardization attempt arose out of a request by PSARC (Pacific Stock Assessment Review Committee) for application of a multiplicative model for effort standardization for English and rock soles.

The overall trend in LPUE for both "option-2" and multiplicative time series is similar and the rate of decline of LPUE for both series is also similar. The trend in effort for the two time series is similar up to the mid-1970s, at which time the "option-2" efforts are significantly higher than those produced from the log-linear model LPUE time series. This is probably due to the higher proportion of incidental catches of rock sole used to compute the "option-2" effort time series.

The fishery in Area 5D, in the late 1970s was primarily a directed fishery on Pacific cod at depths deeper than where rock sole are most abundant, while in recent years, a fishery for arrowtooth flounder has taken place in the deeper depths (>40 fath) on Two Peaks-Butterworth grounds. Rock sole has been caught incidentally in both of those fisheries and with no directed fishery for rock sole in shallow (10-29 fath) depths, all of the fishing effort directed at species such as Pacific cod and Arrowtooth flounder in the deeper depths is allocated to rock sole by the "option-2" method. Thus, the "option-2" LPUE for rock sole in later years is probably too low while effort calculated for rock sole from this index would be too high.

4.5.1.10. General biological information

Length frequency anomalies (see section 4.3.1.3) for 1946-83 were published in Fargo (1985). The anomaly time series has been updated through 1986 and anomalies for 1983-86 are shown in Figure 4.5. The anomalies illustrate the low recruitment mode for this stock in the mid 1980s. Recently, aged samples from the fishery have confirmed that landings are predominantly made up of older fish. The first length frequency samples collected in 1987, however, indicate a significant increase in the numbers of new recruits to the fishery in Area 5D.

4.5.1.11. Condition of the stock

The rock sole stock in Area 5D is considered to have been at low levels since the early 1980s on the basis of trends in LPUE. The recruitment mode for the stock has also been at low levels since the early 1980s according to length frequency and ageing data, but increases in yield may occur over the next 2 or 3 years if the increase in recruitment indicated by length frequency samples obtained from the 1987 fishery is real.

4.5.1.12. Yield options

Managers have indicated, in the past, that rock and English soles do not have management priority within the Hecate Strait region. Consequently, quota overruns have occurred for both of these species with the unregulated directed fishery for Pacific cod (most productive species in the region). The current trip limit regulation for rock sole is aimed at discouraging a target fishery on the species while abundance/recruitment is low. The trip limit allows for retention of incidental catches of rock sole in the Pacific cod and Arrowtooth flounder fisheries. When recruitment/abundance increases, the trip limit level can be adjusted to be consistent with a sustainable yield for the stock at a new abundance level, permitting a directed fishery.

Low risk sustainable Yield option -- Removals of approximately 100 tonnes from 1984-86 have not resulted in any reduction of LPUE regardless of which LPUE time series is used. The 30,000 lb trip regulation currently in effect for rock sole in Hecate Strait is consistent with this option.

High risk sustainable option -- Removals of 400-500 tonnes in 1980-81 did not result in a reduction of LPUE as indicated by the multiplicative model but information from length frequency data indicates that recruitment during the late 1970s was fairly high and thus the stock size in 1980-81 was higher than the stock size at present. Consequently, removals of as much as 400 t would constitute a significantly greater risk of overfishing to the stock at this time.

Non sustainable Yield option -- A free fishery at this time would increase the probability of recruitment overfishing. Yields greater than 400 t are considered a risk at this time.

4.5.2. English sole - Area 5D

4.5.2.1. Introduction

Detailed stock assessments were last conducted in 1984 and are summarized in Fargo (1985). Catch-effort time series for the species are updated here. Length frequency data is also updated in the form of length anomalies in numbers/hr. A multiplicative model incorporating depth and vessel effects was used to standardize effort for comparison to the effort standardization method used in previous assessments (Fargo 1985; Fargo 1985; Fargo 1987).

4.5.2.2. The fishery

Area 5D in Hecate Strait contains the only significant fishery for English sole (Parophrys vetulus) in British Columbia. The principal fishing grounds are Two Peaks-Butterworth (April-September) and White Rocks (October-March). In recent years, minor amounts of English sole have been landed from locations in Area 5C (Horseshoe and Bonilla). It is unclear whether these landings derive from another stock of English sole in Hecate Strait, but these landings are of minor importance at present and are ignored in this assessment.

4.5.2.3. Landing statistics

Landing statistics for English sole in Area 5D have been standardized using two methods. The first method is described in Section 4.4.1.3. The second method involved the use of a multiplicative log-linear model as was suggested in an external review of flatfish stock assessments by PSARC (Pacific Stock Assessment Review Committee) in 1984. The multiplicative model described in Section 4.5.1.9 was applied to Area 5D English sole. Standardized landing statistics for Area 5D English sole produced from the two methods are presented in Table 4.8, and Figure 4.6.

Long-term trends in LPUE are similar for time series produced from the two methods, however, a greater decline in the early years (1956-70) is evident in the "option-2" LPUE. The effort time series are similar from 1956-62 and 1967-86, but the "option-2" effort figures are significantly larger from 1963-66. The period 1963-66 was one of high Pacific cod production, and, doubtless, the amount of effort allocated to English sole over this time period by the "option-2" method was affected by the directed fishery on Pacific cod. Long-term trends of increasing effort are apparent in both time series.

In 1986, "option-2" LPUE for English sole decreased significantly from 1985 (Fig. 4.6). Part of the reason for this may have been the burgeoning fishery for arrowtooth flounder in the Two Peaks-Butterworth area. Closer examination of the "option-2" landing statistics for 1986 showed that arrowtooth flounder was the major species in landings from Two Peaks-Butterworth during quarter 2. The depths fished for arrowtooth flounder are deeper than the normal English sole depths, but the "option-2" method would allocate that effort to English sole. This would have the effect of biasing (low) the 1986 "option-2" LPUE figure for English sole.

4.5.2.4. General biological information

In order to monitor recruitment for English sole in Area 5D, a series of length frequency anomalies (see section 4.3.1.3) have been produced (Fig. 4.7). These anomalies have been produced in numbers per hour which facilitates comparison of relative recruitment among years. In 1985, recruitment appeared to increase significantly, but this did not hold up through 1986, an indication of a relatively weak year-class, or over-exploitation.

Figure 4.8 presents a set of histograms for the 1982-86 fishery samples. These plots depict the numbers of fish caught in each centimeter length interval in one hour of standardized trawling effort. A general trend of decreasing numbers of larger (older) fish being caught in the fishery is apparent here. The reference point of 40 cm was chosen arbitrarily and represents a length consistent with fish fully recruited.

4.5.2.5. Condition of the stock

On the basis of trends in LPUE in recent years from both time series presented here, the Area 5D English sole stock is considered to be at average to low levels.

Length frequency data for the stock indicates a low recruitment mode and signs of juvenescence, common to an overfishing situation.

4.5.2.6. Yield options

The problems in regulating the English sole fishery have been discussed in Section 4.5.1.12.

Low risk sustainable yield option -- Yields of 400 t will decrease the probability of fishing up observed over the past 5 years. As a caveat here, the increasing Pacific cod fishery in Hecate Strait will negate a trip limit regulation for English sole at the present time by simply increasing discards while a catch quota for English sole is certain to negatively impact Pacific cod production if enforced.

High risk sustainable yield option -- With the current low recruitment mode, 600 tonne yields can probably be sustained. These figures are based on LPUE trends from 1982-86 from both effort standardization models. However, biological data indicates some signs of over-fishing with yields averaging 600 tonnes over the last 5 years.

Non sustainable yield option -- Yields of greater than 600 t are not considered to be sustainable for the Area 5D stock assuming the current recruitment mode is low.

4.5.3. Dover sole

4.5.3.1. Introduction

The last detailed stock assessment for Dover sole is contained in Fargo (1985). As in the past, estimates of yield for this assessment are determined by surplus production analysis of standardized catch/effort data.

4.5.3.2. The fishery

The fishery for Dover sole takes place at depths of 50-80 fathoms at Dundas ground in north Hecate Strait (May-October) and 100-200 fathoms at Langara Deep and Frederick Island (December-April). The seasonal shift in the fishery is related to the annual bathymetric migrations Dover sole undergo for the purpose of spawning. (Winter at Langara Deep.)

4.5.3.3. Landing statistics

Standardized landing statistics for Dover sole for 1970-86 are presented in Table 4.9. LPUE for Dover sole was standardized using a log-linear multiplicative model similar to Gavaris (1980), and Kimura (1981). Nominal and standardized LPUE time series are presented in Figure 4.9. The LPUE time series show a declining trend from 1970-79 corresponding to the effect of initial exploitation on the stock followed by an upward trend from 1980-86.

4.5.3.4. General biological information

Length frequency information compiled from 1970-86 indicates no change in mean length and no significant change in the frequency distribution for this time period either.

4.5.3.5. Condition of the stock

The LPUE time series indicates that the 5CDE Dover sole stock is presently stable, with no observable sign of overfishing. The length frequency data also does not indicate overfishing. MSY estimated from effort and LPUE using Gulland's (1961) method is 861 t, while the optimum effort level is estimated at 1779 hours. The method is described in Fargo (1985).

4.5.3.6. Yield options

Low risk sustainable option -- The analysis above indicates that 800 t yields are sustainable for the Area 5CDE Dover sole stock. However, the rising trend in LPUE with removals of 800 t over the last several years indicates that the maximum sustainable yield may be higher than 800 t.

High risk sustainable option -- With 1793 hours of effort in 1986 (close to F_{opt}), a yield of over 1000 t was achieved. This indicates that the actual MSY for this stock may be closer to 1000 t. However, landings in excess of 1000 tonnes have occurred in only 1 of the last 10 years and, at the present time, no prediction can be made regarding the response of the stock to a harvest of this level.

4.5.4. Arrowtooth flounder

4.5.4.1. Introduction

The first comprehensive stock assessment for arrowtooth flounder was presented in Fargo (1987). In addition to updating landing statistics, the following assessment includes a series of yield simulations for the species which provide more information on how increasing exploitation rates are likely to affect the population.

4.5.4.2. The fishery

The major portion of the commercial fishery for arrowtooth flounder in Hecate Strait has taken place at Two Peaks and Butterworth grounds at depths of 40-60 fathoms during quarters two and three. The fishery has increased significantly, but the limiting factor is still lack of markets because of the poor quality of flesh for the species.

4.5.4.3. Landing statistics

Landing statistics for arrowtooth flounder in Hecate Strait listed by utilization are contained in Table 4.10. Landings for arrowtooth flounder have increased in recent years, but still have not approached the peak landings of the mid-1970s. Fish processing companies are reporting new markets for arrowtooth flounder, however, and landings will probably continue to increase for the next few years.

4.5.4.4. General biological information

A population yield simulation model (Walters 1969) was applied to the arrowtooth flounder population in Hecate Strait. The model simulates yield for a population over a 50-year period, given information on age structure, growth, natural mortality, fishing mortality, and stock-recruit parameters. Growth parameters for arrowtooth were estimated from age composition samples obtained from the 1980 arrowtooth biomass survey of Hecate Strait (Fargo et al. 1981). Growth parameters estimated were L_∞=65 cm, k=0.12, t_0=-2.80. Natural mortality rate for the yield calculations was assumed to be 0.20. Starting age structure for the model was assumed to be that of the combined aged samples from the 1980 biomass survey. Parameters for a flat-topped Ricker stock-recruit relationship were used during the simulation.

Results from a 50-year forward simulation indicated a total of 280,000 tonnes of yield over this time period (Fig. 4.10). Maximum yields were achieved with a fishing rate of 0.4-0.6 with an age of recruitment of 4 years.

4.5.4.5. Condition of the stock

The information from landing statistics and biological data such as length frequencies for the species is too sparse to reveal trends in abundance and size composition. Yield simulations indicate that the maximum sustainable yield for the species is considerably higher than current removals (including estimated discards and landed catch).

4.5.4.6. Yield options

Sustainable Yield option -- At the present time, catches of 5000-6000 t are estimated to be sustainable on the basis of yield simulations for the population.

Non-sustainable option -- Yields greater than 6000 t do not appear to be sustainable on the basis of yield simulations performed.

Table 4.1. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock" 1942-86.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?	-	1,561	1964	71	530	601
1943	?	-	2,264	1965	140	658	798
1944	?	-	1,489	1966	118	512	630
1945	?	-	718	1967	106	259	365
1946	?	-	906	1968	114	233	347
1947	?	-	627	1969	255	142	397
1948	?	-	1,321	1970	80	198	278
1949	?	-	1,178	1971	74	523	597
1950	?	-	854	1972	22	561	583
1951	?	-	794	1973	211	452	663
1952	?	-	948	1974	230	684	914
1953	?	-	748	1975	474	465	939
1954	?	-	664	1976	304	453	757
1955	?	-	415	1977	157	311	468
1956	40	585	625	1978	287	126	413
1957	9	629	638	1979	256	92	348
1958	19	609	628	1980	147	115	262
1959	33	1,072	1,105	1981	125	180	305
1960	233	974	1,207	1982	45	232	277
1961	375	1,109	1,484	1983	179	183	362
1962	215	850	1,065	1984	237	218	455
1963	90	658	748	1985	122	147	269
				1986	75	197	272

Table 4.2. Canada-U.S. landings (t) of petrale sole from the "northern stock" 1942-86.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total	Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-	1964	183	421	163	767
1943	-	-	-	-	1965	300	418	202	920
1944	499	303	-	802	1966	264	469	260	993
1945	270	1,535	193	1,998	1967	169	485	176	830
1946	623	1,258	494	2,375	1968	293	266	137	696
1947	469	986	769	2,224	1969	262	114	22	398
1948	943	920	3,011	4,874	1970	136	56	22	214
1949	316	429	1,644	2,390	1971	127	97	55	280
1950	694	569	700	1,963	1972	50	154	33	237
1951	305	326	642	1,273	1973	197	211	24	432
1952	265	305	574	1,144	1974	196	283	14	493
1953	235	450	46	731	1975	234	156	27	417
1954	712	234	300	1,237	1976	153	132	30	315
1955	452	462	94	1,008	1977	58	73	24	155
1956	291	528	53	872	1978	21	63	13	97
1957	1,320	333	216	1,869	1979	10	57	39	106
1958	174	227	171	572	1980	31	40	33	104
1959	227	160	216	603	1981	15	41	42	98
1960	93	212	120	425	1982	30	61	16	107
1961	277	171	102	550	1983	29	161	35	225
1962	295	343	165	803	1984	77	79	24	180
1963	202	537	82	821	1985	50	81	22	153
					1986	24	120	25	169

Table 4.3. Coastwide Canadian petrale sole landings by trip category January-March 1970-86 (lbs landed).

Year	1,000-4,999	5,000-9,999	10,000-14,999	15,000-19,999	20,000-24,999	25,000-29,999	30,000-34,999	35,000-39,999	40,000-44,999	45,000-49,999	50,000-	Total (t)
1970	22	0	2	0	0	0	0	0	1	0	0	37
1971	25	2	1	0	0	0	0	0	0	0	0	14
1972	9	1	0	0	0	0	0	0	0	0	0	5
1973	14	0	0	0	0	0	0	0	0	0	0	5
1974	4	0	0	0	0	0	0	0	0	0	0	1
1975	7	0	0	0	0	0	0	0	0	0	0	2
1976	6	0	0	0	0	0	0	0	0	0	0	0
1977	11	0	0	0	0	0	0	0	0	0	0	3
1978	17	0	0	0	0	0	0	0	0	0	0	4
1979	27	0	0	0	0	0	0	0	0	0	0	3
1980	51	0	1	1	0	0	0	0	0	0	0	21
1981	62	4	2	1	0	0	2	0	0	0	0	69
1982	39	3	2	3	1	0	1	0	0	0	0	72
1983	42	1	0	1	1	2	0	0	0	0	0	63
1984	52	5	2	0	0	0	0	0	0	0	0	37
1985	96	2	4	2	2	0	0	0	0	0	0	89
1986	88	4	2	2	0	0	0	0	0	0	0	60

Table 4.4. Standardized Canada-U.S. landing statistics for rock sole from Area 5A, January-December 1956-85.

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	551	1328	415
1957	511	1780	287
1958	501	1920	261
1959	212	1293	164
1960	397	1640	242
1961	237	1139	208
1962	196	1719	114
1963	161	1288	125
1964	156	1642	95
1965	157	1040	151
1966	330	1803	183
1967	252	1292	195
1968	435	2042	213
1969	293	2203	133
1970	167	1144	146
1971	135	1000	135
1972	58	763	76
1973	57	722	79
1974	74	1451	51
1975	37	597	62
1976	182	3309	55
1977	83	1766	47
1978	79	1129	70
1979	202	1474	137
1980	238	1384	172
1981	114	726	157
1982	189	1512	125
1983	124	1824	68
1984	142	1214	117
1985	56	737	76
1986	23	1769	13

[a] Effort = (Landings)(1000)/LPUE.
[b] LPUE -- Area 5A, April-September.

Table 4.5. Standardized Canada-U.S. landing statistics for rock sole from Area 5B, January-December 1956-85.

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	307	853	360
1957	206	619	333
1958	379	1606	236
1959	344	1339	257
1960	503	1863	270
1961	416	1770	235
1962	531	2091	254
1963	517	1958	264
1964	482	2472	195
1965	568	2021	281
1966	772	2339	330
1967	741	2487	298
1968	392	1774	221
1969	652	2751	237
1970	245	1161	211
1971	368	2079	177
1972	382	2748	139
1973	324	5586	58
1974	371	7275	51
1975	408	4250	96
1976	368	4182	88
1977	188	3133	60
1978	217	2932	74
1979	208	2667	78
1980	410	1925	213
1981	220	2588	85
1982	155	3039	51
1983	206	2424	85
1984	87	2071	42
1985	170	1717	99
1986	135	2596	52

[a] Effort = (Landings)(1000)/LPUE.
[b] LPUE -- Area 5B, April-Sept.

Table 4.6. Standardized Canada-U.S. landing statistics for rock sole from Area 5C, January-December 1956-85.

Year	Landings (t)	Effort (h)[a]	LPUE (kg/h)[b]
1956	397	570	699
1957	726	1396	520
1958	368	944	390
1959	249	1078	231
1960	471	1186	397
1961	110	350	314
1962	322	651	495
1963	155	451	344
1964	244	1179	207
1965	539	4115	131
1966	961	2921	329
1967	948	1992	476
1968	811	1940	419
1969	1053	4066	259
1970	694	2410	288
1971	376	1301	289
1972	134	388	345
1973	186	565	329
1974	288	1269	227
1975	383	2176	176
1976	277	1689	164
1977	272	1470	185
1978	356	1240	287
1979	647	2451	264
1980	482	2634	183
1981	126	2377	53
1982	70	1842	38
1983	60	1132	53
1984	64	362	177
1985	28	318	88
1986	86	656	131

[a] Effort = (Landings)(1000)/LPUE.

[b] LPUE -- Area 5C, April-Sept.

Table 4.7. Standardized Canada-U.S. landing statistics for rock sole from Area 5D, January-December 1956-85.

Year	Landings (t)	Effort (h)[a]	Effort (h)[b]	LPUE (kg/h)[c]	LPUE (kg/h)[d]
1956	763	1538	1109	496	688
1957	425	2361	513	180	828
1958	888	742	664	1197	1336
1959	167	1099	222	152	751
1960	656	989	541	663	1211
1961	634	402	317	1578	1995
1962	507	754	295	672	1715
1963	726	1287	664	564	1093
1964	499	1102	599	453	832
1965	340	1255	194	271	1752
1966	1583	3244	1283	488	1233
1967	1214	918	534	1323	2271
1968	1555	3337	1938	466	802
1969	1356	2122	1747	639	776
1970	709	1672	1505	424	471
1971	1127	2466	2614	457	431
1972	381	2268	768	168	496
1973	321	2568	265	125	1211
1974	334	2212	456	151	732
1975	821	5864	1115	140	736
1976	1161	5609	2608	207	445
1977	574	8085	1393	71	412
1978	518	3453	1083	150	478
1979	666	11288	1924	59	346
1980	495	7174	1371	69	361
1981	458	8035	1082	57	423
1982	221	3508	462	63	478
1983	187	2922	328	64	570
1984	124	5905	293	21	423
1985	84	7636	253	11	276
1986	133	6333	361	21	368

[a] Effort = (landings)(1000)/option 2 LPUE.

[b] Effort = (Landings)(1000)/LPUE standardized by log linear model.

[c] LPUE -- Two Peaks-Butterworth, April-September (option 2 method, Westrheim 1977).

[d] LPUE -- Two Peaks-Butterworth standardized by log linear model.

Table 4.8. Standardized Canada-U.S. landing statistics for English sole, Area 5D, January-December 1956-85.

Year	Landings (t)	Effort (h)[a]	Effort (h)[b]	LPUE (kg/h)[c]	LPUE (kg/h)[d]
1956	935	1300	3085	719	303
1957	539	1653	2542	326	212
1958	674	2332	3604	289	187
1959	901	2468	3337	365	270
1960	1079	1505	2738	717	394
1961	865	1676	2396	516	361
1962	436	1232	1602	354	272
1963	369	3101	1476	119	250
1964	420	2308	1673	182	251
1965	391	3491	1761	112	222
1966	329	5141	1126	64	292
1967	511	2077	915	246	558
1968	632	3144	2784	201	227
1969	725	2571	1835	282	395
1970	920	2402	3511	383	262
1971	482	2708	3089	178	156
1972	356	2211	1202	161	296
1973	598	2265	1573	264	380
1974	459	2318	840	198	546
1975	922	3415	2195	270	420
1976	946	6757	4060	140	233
1977	972	7594	4811	128	202
1978	495	4714	2964	105	167
1979	744	8651	3895	86	191
1980	796	7044	4145	113	192
1981	1148	7705	5655	149	203
1982	401	3457	2067	116	194
1983	396	2829	1596	140	248
1984	606	3367	2578	180	235
1985	547	2509	3038	218	180
1986	322	2800	1041	115	290

[a] Effort = (landings)(1000)/option-2 LPUE.

[b] Effort = (landings)(1000)/multiplicative model LPUE.

[c] LPUE = Two Peaks-Butterworth, April-September option-2.

[d] LPUE = Two Peaks-Butterworth, April-September - multiplicative model.

Table 4.9. Standardized Canada-U.S. landing statistics for Dover sole, Areas 5C, D, E, 1970-85.

Year	Landings (t)[a]	Effort (h)[b]	LPUE (t/h)[c]
1970	965	1413	0.748
1971	903	1364	0.628
1972	922	1478	0.625
1973	768	961	0.819
1974	767	916	0.773
1975	882	1370	0.620
1976	1022	2349	0.416
1977	577	1826	0.299
1978	483	1121	0.502
1979	697	2723	0.288
1980	807	2431	0.392
1981	840	1791	0.451
1982	512	1347	0.398
1983	693	1227	0.513
1984	953	2015	0.558
1985	830	1766	0.470
1986	1040	1793	0.580

[a] 0% qualified Canadian landings, 5C, D, E.

[b] Effort (h) = landings (t)/LPUE (t/h).

[c] LPUE = 25% qualified landings -- Dundas standardized by log linear model.

Table 4.10. Arrowtooth flounder landings from Hecate Strait by utilization 1956-85.

Year	Food	Animal food	Reduction	Total
1956	-	534	-	534
57	-	141	-	141
58	-	115	-	115
59	-	300	-	300
1960	-	384	-	384
61	-	671	-	671
62	-	654	-	654
63	-	84	-	84
64	-	202	-	202
65	4	142	-	146
66	4	248	-	252
67	0	417	-	417
68	4	466	-	470
69	0	528	-	528
1970	4	201	10	215
71	0	20	0	20
72	88	122	0	210
73	420	36	0	456
74	269	0	0	269
75	632	0	0	632
76	1051	0	0	1051
77	1005	0	0	1005
78	1365	0	9	1374
79	1527	0	-	1527
1980	1013	0	-	1013
81	528	0	-	5280
82	144	0	-	144
83	95	0	-	95
84	212	0	-	212
85	507	0	-	507
86	352	21	-	373
Total	9224	5286	19	14529

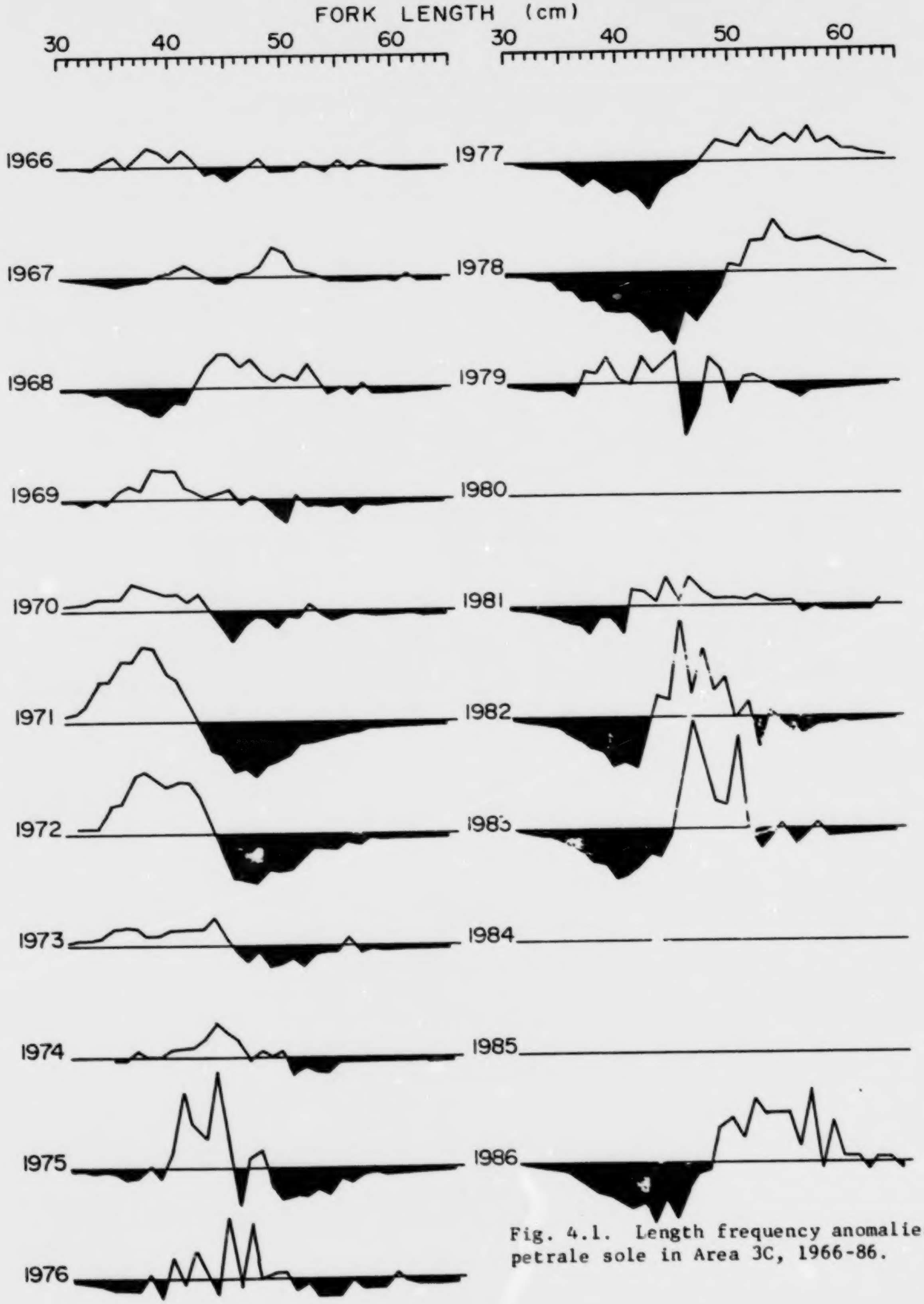

Fig. 4.1. Length frequency anomalies for petrale sole in Area 3C, 1966-86.

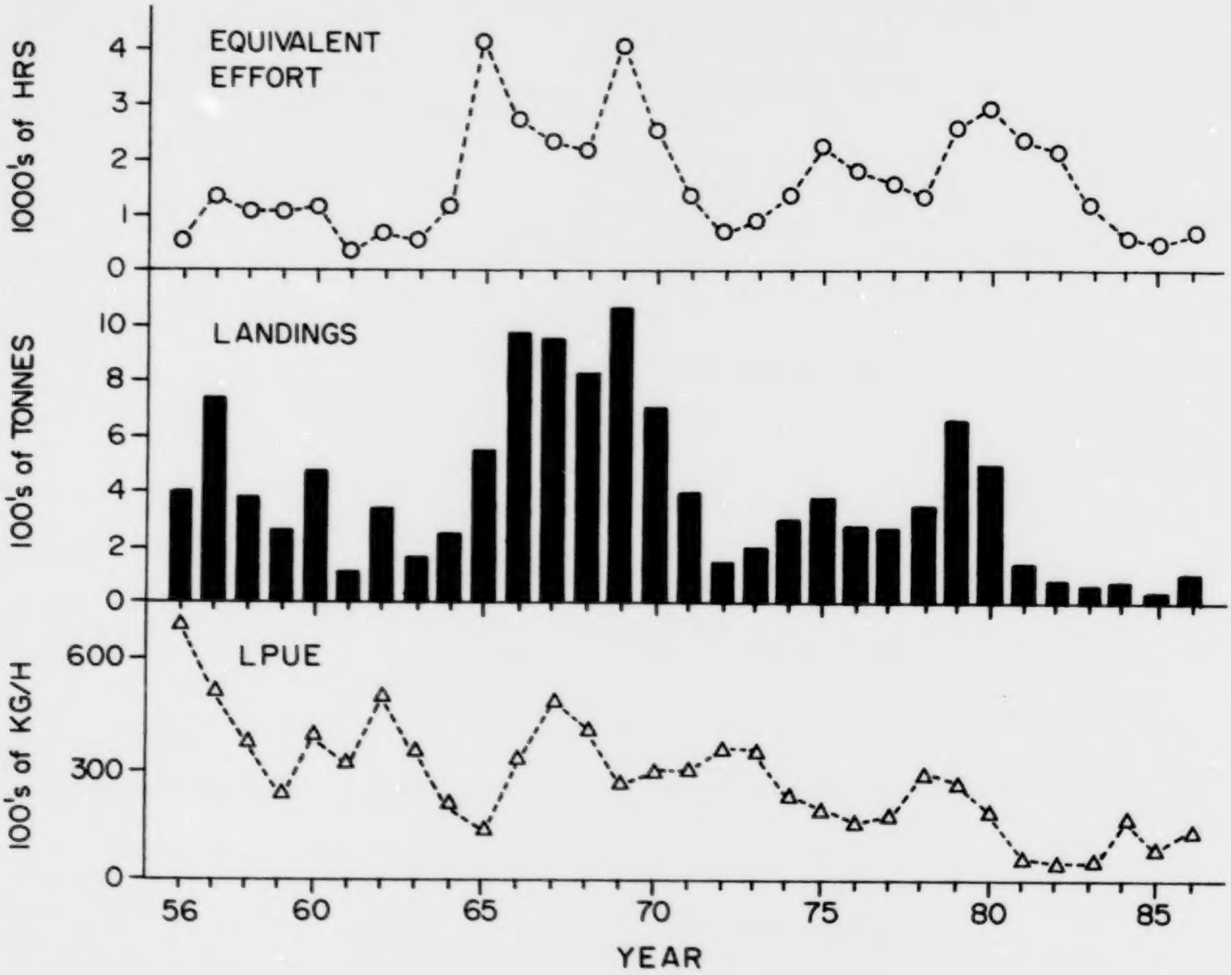

Fig. 4.2. Standardized landing statistics for rock sole from Area 5C, 1956-86.

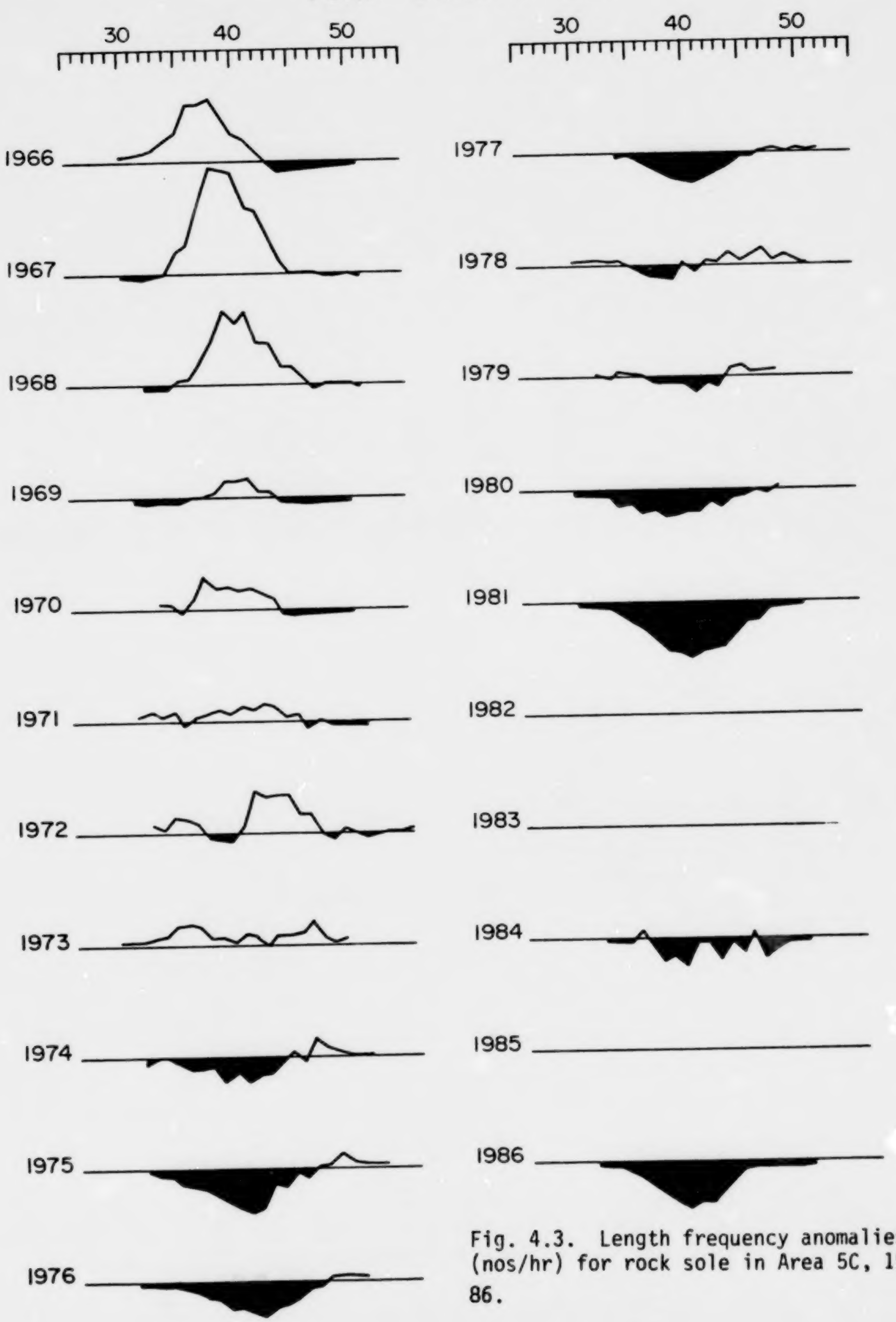

Fig. 4.3. Length frequency anomalies (nos/hr) for rock sole in Area 5C, 1966-86.

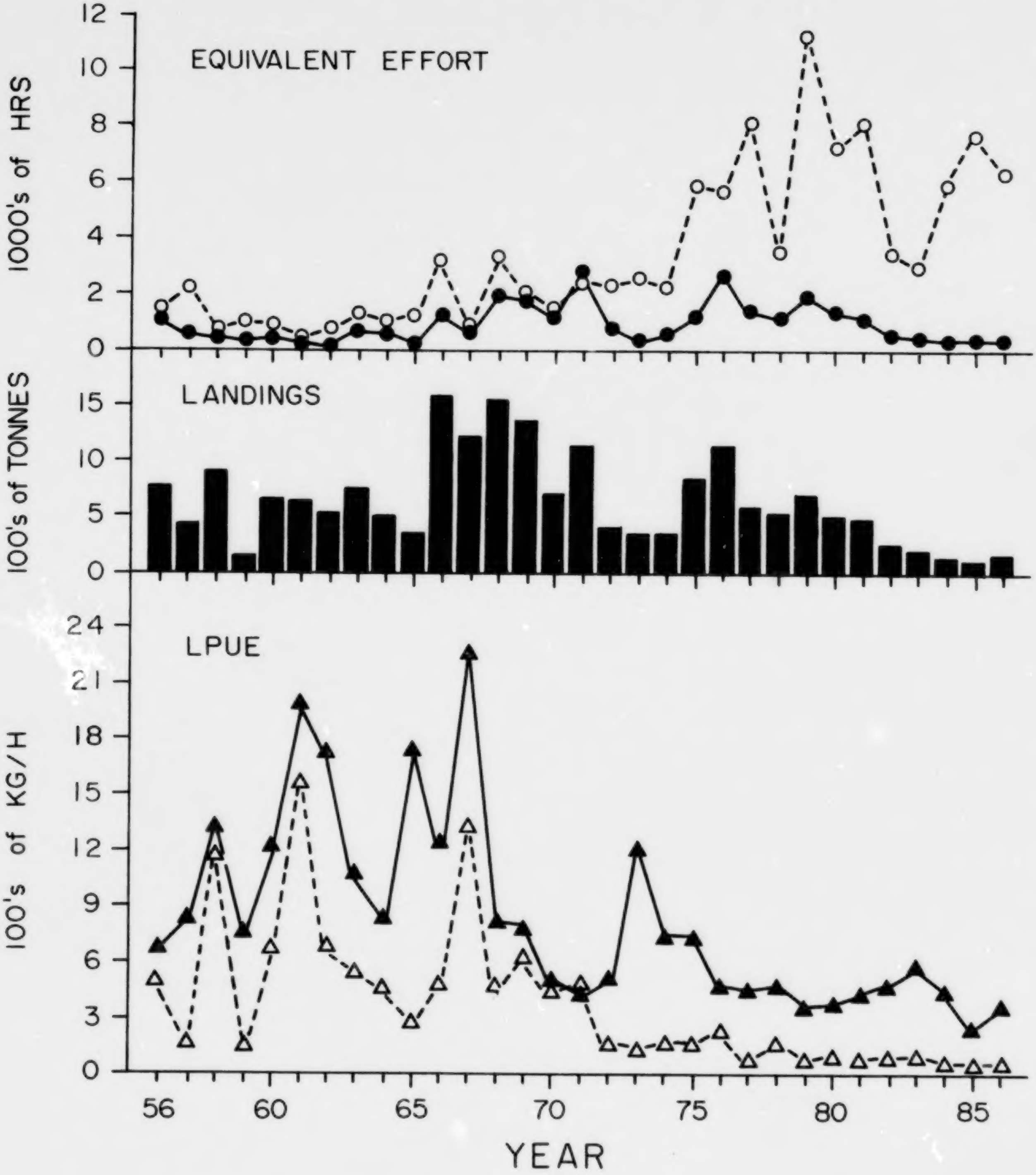

Fig. 4.4. Standardized landing statistics for rock sole in Area 5D, 1956-86. Open symbols are time series calculated using Westrheim (1983), and Westrheim and Foucher (1985) method. Solid symbols are time series from the multiplicative model.

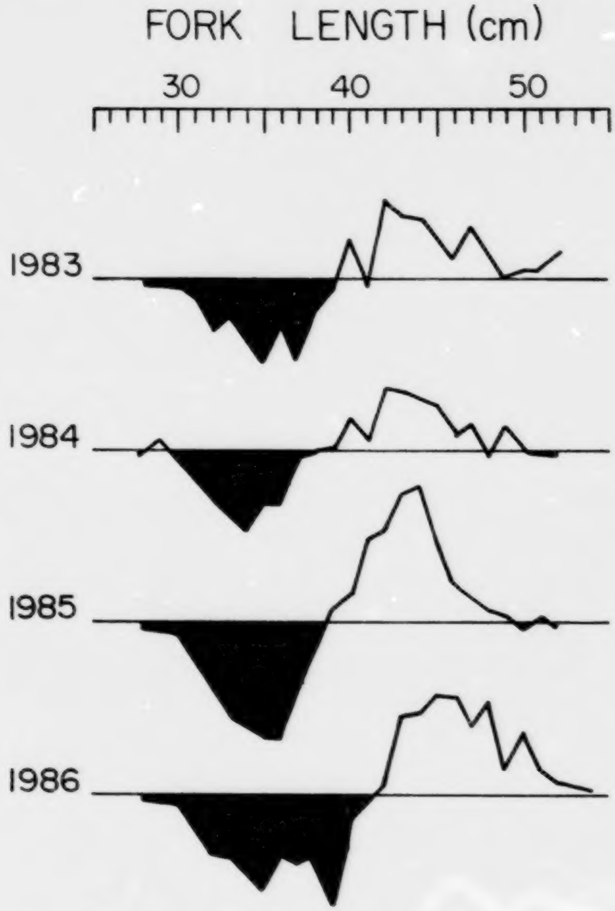

Fig. 4.5. Length frequency anomalies for rock sole in Area 5D, 1983-86.

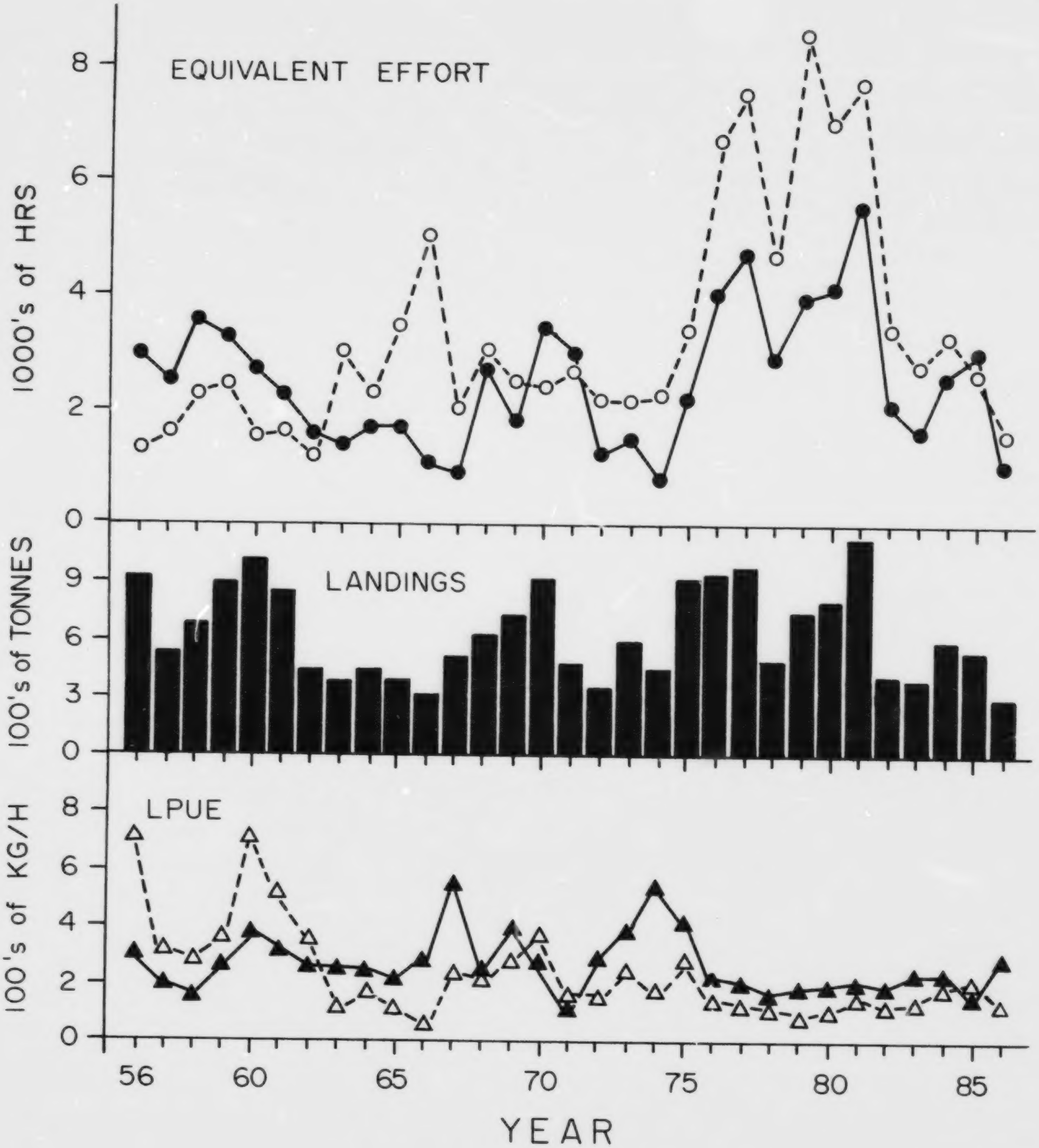

Fig. 4.6. Standardized landing statistics for English sole in Area 5D, 1956-86. Open symbols are time series calculated from Westrheim (1983) and Westrheim and Foucher (1985). Solid symbols are from the multiplicative model.

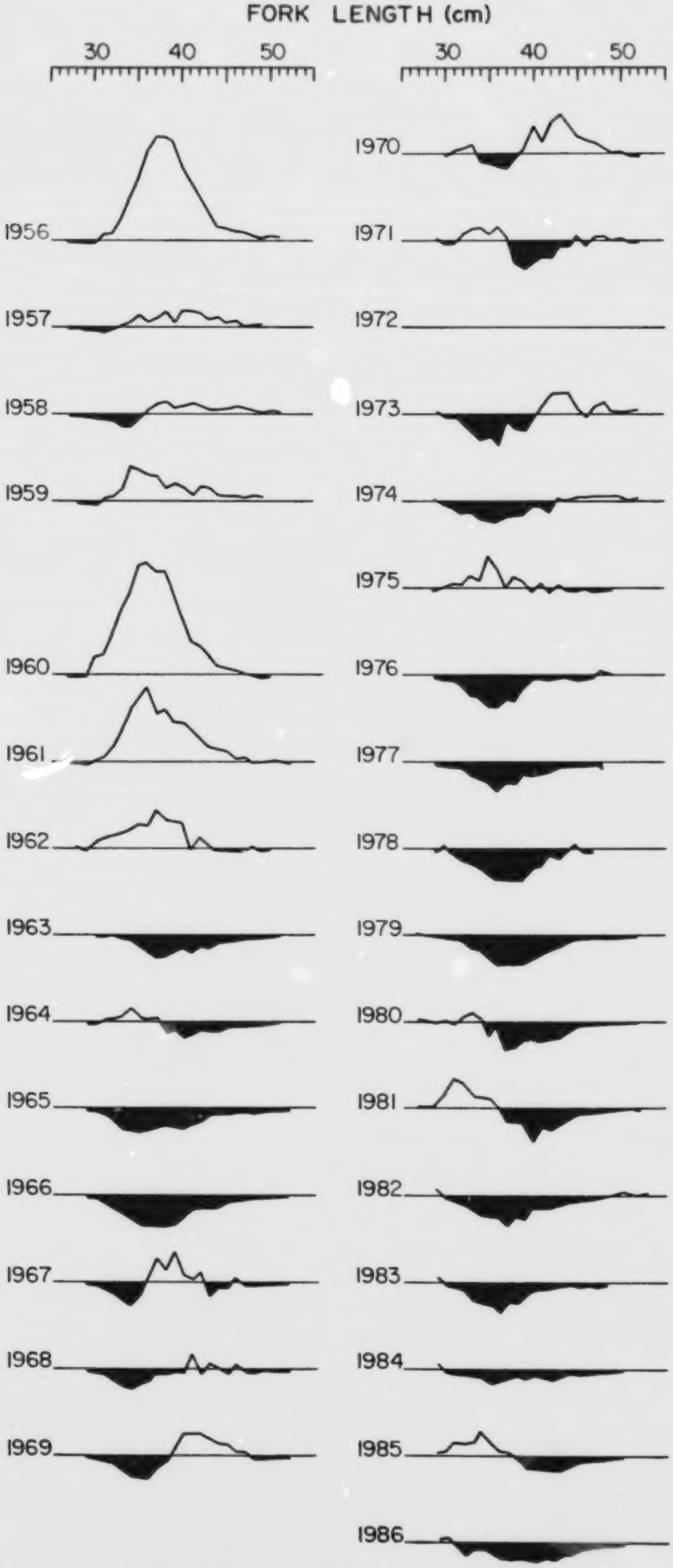

Fig. 4.7. Length frequency anomalies (nos/hr) for English sole in Area 5D, 1956-86.

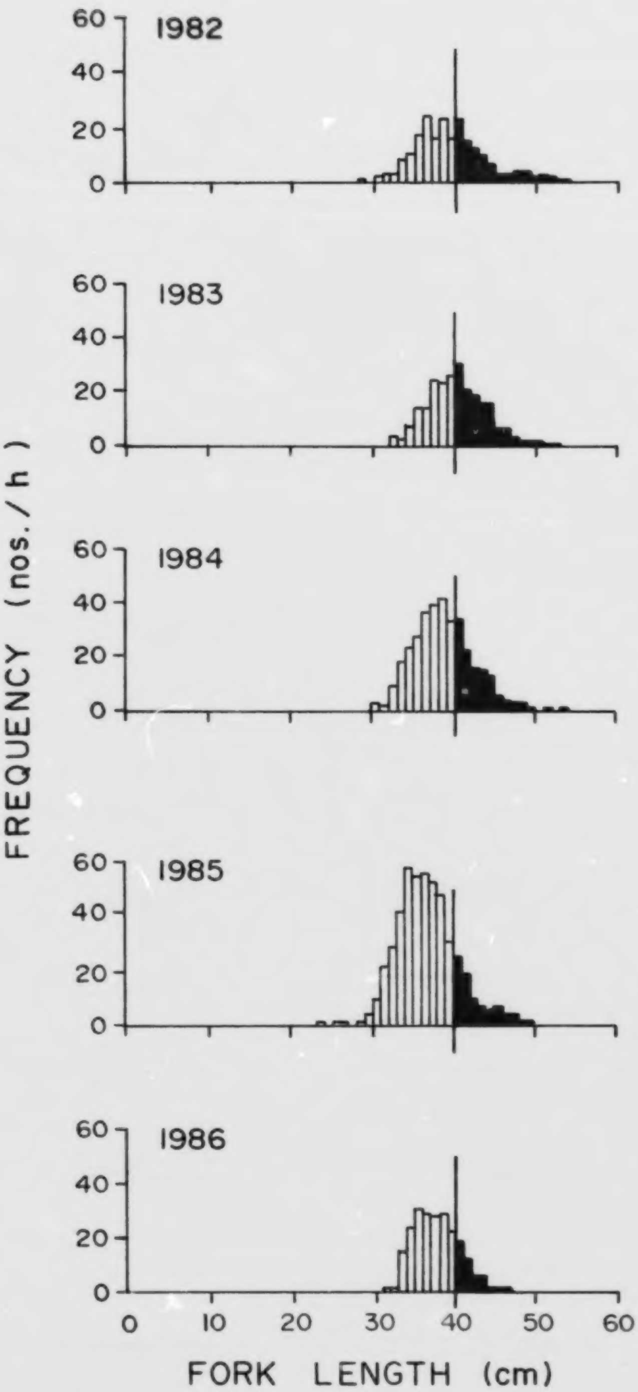

Fig. 4.8. Length frequency samples (nos/hr) from the commercial fishery for English sole in Area 5D, 1982-86.

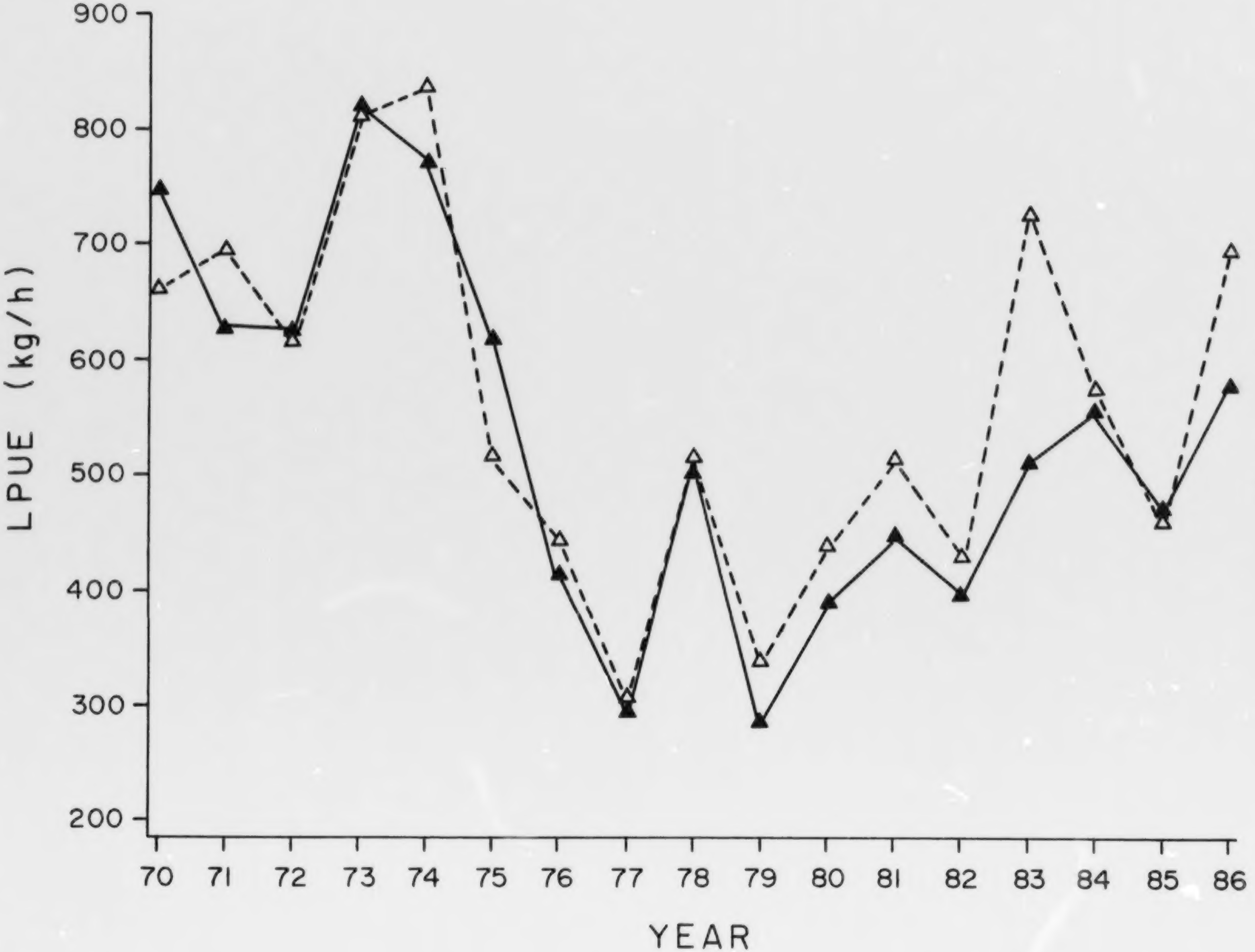

Fig. 4.9. Nominal and standardized (solid) LPUE time series for Dover sole in Area 5CDE, 1970-86.

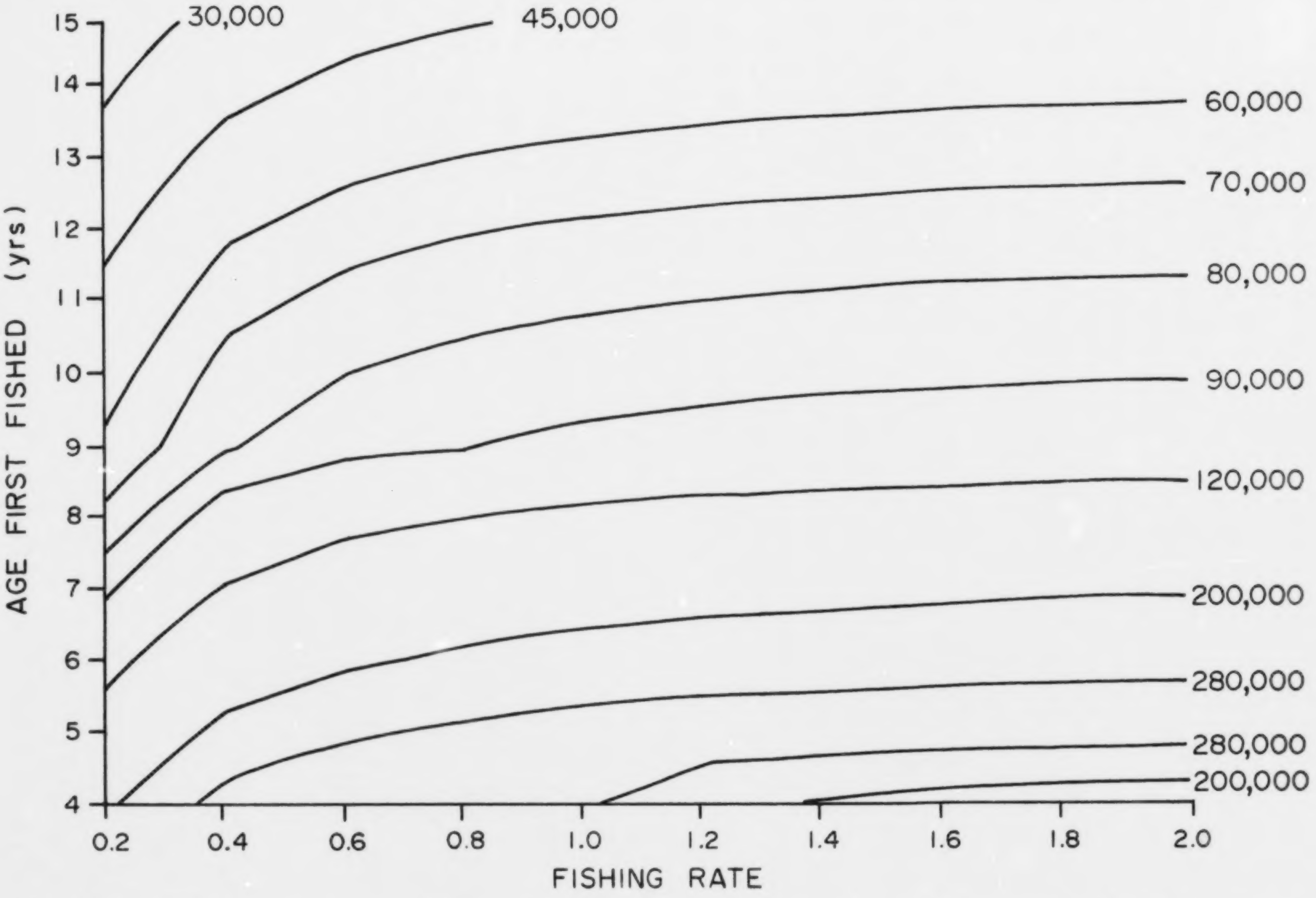

Fig. 4.10. Yield isopleths from 50-year forward simulations of Hecate Strait arrowtooth flounder. The numbers in the body of the graph are yield potentials in tonnes for a 50-year period.

5.0 SABLEFISH

by M.W. Saunders, W. Shaw and G.A. McFarlane

5.1 Coastwide

5.1.2 Landing statistics

In 1986 a total of 4411 t of sablefish were landed coastwide by trap, trawl, and longline. Landings from the west coast of the Queen Charlotte Islands, Queen Charlotte Sound, and Hecate Strait increased from 2298 t in 1985 to 2560 t in 1986, with the majority (86.6%) caught by trap (Table 5.1).

Landings from the west coast of Vancouver Island decreased to 1851 t in 1986 from 2650 t in 1985. The majority of fish were trap-caught (55.5%), down considerably from 86.6% in 1985 (Table 5.2). This was countered by an increase in longline landings from 159 t in 1985 to 459 t in 1986.

Trawl landings increased from 94 t in 1985 to 365 t in 1986 from the west coast of Vancouver Island and increased from 135 t in 1985 to 185 t in 1986 from all other areas (Tables 5.1 and 5.2).

5.1.3 General biological information

Length frequencies from fish tagged in 1977 off the west coast of the Queen Charlotte Islands and off the west coast of Vancouver Island are presented in Figures 5.1a and 5.1b. The frequency from Queen Charlotte Islands ranged from 42 to 98 cm with a mode at 55 cm and is strongly skewed right. The Vancouver Island frequency ranged from 46 to 101 cm with a mode of 66-70 cm. These frequencies indicate that fish off the Queen Charlottes tend to be larger than those off Vancouver Island.

This trend is supported by length frequencies collected during 1986 off the west coast of Vancouver Island and off the west coast of the Queen Charlotte Islands, presented in Figures 5.1c and 5.1d. The range, modes and overall shape of the distibutions have remained comparable over the period 1977 to 1986, an indication of stability in the population.

5.1.4 Condition of the stock

A method to standardize sablefish trap LPUE was developed. In brief, LPUE was standardized by trap type, fishing area and vessel. Preliminary results comparing nominal LPUE estimates to standardized LPUE estimates by major fishing area are presented in Table 5.3 and Figure 5.2. Most of the variability between nominal and standardized LPUE trends occur off Vancouver Island and in Queen Charlotte Sound. Off the Queen Charlotte Islands both nominal and standardized LPUE exhibit similar trends. Standardized LPUE off the Queen Charlotte Islands in 1986 decreased to 16.8 kg/trap from 18.2 kg/trap in 1985. In Queen Charlotte Sound standardized LPUE in 1986 increased to 20.3 kg/trap from 17.4 kg/trap in 1985. Off Vancouver Island standardized LPUE decreased to 10.3 kg/trap in 1986 from 15.6 kg/trap in 1985.

The approach taken in this assessment is identical to that reported in the 1986 assessment (Saunders et al. 1987). A forward simulation model (Tyler 1982) was used to project sablefish biomass and yield from 1980 to 1995. The numbers at age used as the starting vector for the forward simulation were calculated using Virtual Population Analysis (VPA) (Gulland 1983).

The VPA was run using seven years of age composition data 1979-1985. VPA runs using a range of terminal F's and natural mortality (M) rates were conducted to investigate the sensitivity of the analysis to these starting parameters. As discussed by Gulland (1983), the numbers at age for the younger age-groups are not drastically affected by the terminal F value, however the estimate of natural mortality is critical, especially with a long-lived species such as sablefish. At each natural mortality rate, the numbers at age differ by less than two percent over the range of terminal F's while, at each terminal F level, the numbers at age over the range of natural mortality rate differ by a factor of close to two (Table 5.4). The level of natural mortality assumed to be the most accurate was M=0.1 (McFarlane et al. 1985).

The catch at age data used in the VPA are presented in Table 5.5. The annual estimates of numbers at age, fishing mortality rates (F), total mortality rates (Z), and exploitation rates from the VPA (using M=0.1) are presented in Tables 5.6, 5.7, 5.8, and 5.9, respectively, with totals presented in Table 5.10. The numbers at age 5 in 1983, 1984, and 1985 (Table 5.6) indicate that the 1978, 1979, and 1980 year-classes are moderate to strong in strength. It must be noted however, that because the cumulative F values for the 1979 and 1980 year-classes are less than two, the numbers at age cannot be considered accurate (Pope 1972).

The catch at age also indicates that the fishery is becoming increasingly dependent on younger fish. The cause of this age-frequency truncation is believed to be the result of a number of factors. First of all, the increasing price for small fish (<60 cm) since 1984 and the shorter duration of the fishery has led to more smaller fish being landed, resulting in an alteration of partial recruitment factors and an inflation of numbers estimated at recruitment by the VPA. Consequently, to reduce the error in estimating recruitment in the forward simulations, numbers at age 5 from the VPA were used rather than numbers at age 4 which had been used in previous assessments.

Secondly, the truncation could be the result of a masking of the older age classes by the strong 1977 year-class. The sample sizes required to sample the population were derived prior to the arrival of the strong 1977 year-class and may be inadequate for older ages.

Thirdly, the truncation could be the result of fishing down the older ages. If true, then the rapid loss of the older ages and the dependence of the fishery on 10-15 year-classes is cause for concern for a species with documented low periods of recruitment.

Forward simulations (1980 to 1995) were run using the numbers at age for 1979 from the VPA as the starting population. The rates of natural mortality applied in the forward simulation were the same as those used in the corresponding VPA runs. Catches from 1979 to 1987 were included, with the catch in 1987 assumed to be equal to the quota. The numbers recruiting at age 5 were taken from the VPA up to 1985. Beyond 1985, recruitment was assumed to be constant and a range of recruitment levels were employed. The average of the numbers at age 5 in 1980 and 1981 (1975 and 1976 year-classes) was used as a low level of recruitment. These year-classes are recognized as weak to moderate in strength. The numbers at age 5 for the 1978 year-class were used for the moderate to strong recruitment level and the mean of the high and low levels was used as an average level. Beyond 1987, F levels of 0.205 and 0.1025 were used. These correspond to the $F_{0.1}$ and $F_{0.05}$ levels from yield per recruit analysis (McFarlane et al. 1985). While $F_{0.1}$ is assumed to be conservative for most species, it is not known if it is conservative for a long-lived species with low recruitment. It is likely that the acceptable catch level is somewhere between the two.

The projections indicate that with average recruitment the recruited biomass will continue to gradually decline (Fig. 5.3) at an F of 0.205, a result of the decay of the strong 1977 year-class. At an F of 0.1025, however, the recruited biomass increases. The projected yields for 1988 at F levels of 0.205 and 0.1025 are presented in Table 5.11.

The appropriate rates of natural mortality and levels of recruitment introduce the most uncertainty into this assessment. Regarding recruitment, work is currently underway on determining the factors that influence year-class strength. As well, an index of year-class strength based on the abundance of 0+ fish has been under development since 1984. In 1988, the first year-class surveyed will begin recruiting to the fishery as age 4-5 fish and the ability of the survey to predict year-class strength can be assessed.

With the standardization of effort now complete, analysis of the rate of natural mortality (M) will be carried out and incorporated into future assessments.

5.1.5 Yield options

These yields were calculated using an F_{opt} of 0.205 and 0.1025. The assumption here is that the management goal is to optimize the yield per recruit. Using this strategy, strong year-classes such as the 1977 are exploited rapidly with catches remaining high for several years. In the past, strong year-classes have been approximately ten years apart. Although there is indication that moderate to strong year-classes have occurred since 1977 it is possible that persistently poor recruitment could occur again as it did in the mid-1970s. Should this happen, sustainable yields would decrease considerably. If industry is willing to accept the lows with the highs then the current strategy is acceptable. An alternative is to develop a strategy that responds to incoming strong year-classes but maintains a level of biomass that supports, at the very least, some minimum yield required by industry for five to ten years in the event of poor recruitment.

Risk in the yield options below is a function of the uncertainty regarding mortality and recruitment. There exists a strong possibility that the high-risk level may interfere with the future yield. As discussed above, work is currently underway to refine the estimates of mortality and predict the level of recruitment.

Yield option		Yield (t)
Sustainable - low risk	-	3500 t
Sustainable	-	4000 t
Sustainable - high risk	-	4500 t

Table 5.1. Canadian sablefish landing, by gear, from Queen Charlotte Sound, Hecate Strait, and the west coast of the Queen Charlotte Islands, 1973-1986 (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	116.6	21.6	31.7	5.9	392.4	72.6	-	-	540.7
1974	39.0	16.1	38.1	15.7	165.6	68.2	-	-	242.7
1975	149.9	22.7	82.0	12.4	427.9	64.9	-	-	659.8
1976	47.7	10.4	154.2	33.7	255.8	55.9	-	-	457.7
1977	49.8	16.9	98.3	33.4	145.7	49.4	0.9	0.3	294.7
1978	39.0	8.2	40.4	8.5	395.1	83.0	1.4	0.3	475.9
1979	158.7	11.7	132.7	9.8	1067.6	78.5	-	-	1359.0
1980	179.7	9.5	228.6	12.0	1488.3	78.5	-	-	1869.6
1981	238.1	8.7	90.4	3.3	2412.6	88.0	-	-	2741.1
1982	181.8	6.3	88.3	3.1	2595.2	90.1	16.5[d]	0.5	2881.8
1983	108.4	3.5	116.5	3.7	2901.2	92.3	15.6[e]	0.5	3141.7
1984	153.9	6.7	64.8	2.8	2082.2	90.5	-	-	2300.9
1985	298.9	13.0	135.1	5.9	1864.1	81.1	-	-	2298.1
1986	159.3	6.2	184.8	7.2	2215.9	86.6	-	-	2560.0

[a] Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981.

[b] Includes troll, handline, and sunken gillnet (1968 only).

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

[e] Includes troll, handline, sunken gillnet and catch incidental to halibut longline fishery.

Table 5.2. Canadian sablefish landing, by gear, from west coast of Vancouver Island, 1973-1986 (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	3.2	0.8	50.9	12.5	353.4	86.7	Tr	Tr	407.5
1974	2.3	0.9	83.7	33.6	161.5	64.8	1.8	0.7	249.3
1975	2.3	0.9	200.3	81.8	41.5	16.9	0.9	0.4	245.0
1976	41.7	13.3	224.8	71.5	47.6	15.1	0.1	0.1	314.2
1977	27.3	3.5	688.4	87.1	68.9	8.7	5.9	0.7	475.0
1978	18.2	5.1	89.9	25.4	239.5	67.7	6.4	s1.8	1359.0
1979	118.3	17.5	143.4	21.2	409.8	60.5	6.0	0.9	1869.0
1980	69.1	3.6	106.8	5.6	1722.5	90.6	3.0	0.2	2741.1
1981	94.8	8.6	140.2	12.8	862.4	78.6	-	-	2881.8
1982	161.9	13.2	153.2	12.5	913.3	74.2	1.9[d]	0.2	3141.7
1983	343.1	27.1	146.7	11.6	777.0	61.3	-	-	2300.9
1984	211.2	13.9	120.0	7.9	1188.9	78.2	-	-	1890.5
1985	159.4	8.4	93.9	5.0	1637.2	86.6	-	-	2560.0
1986	459.2	24.8	365.4	19.7	1026.6	55.5	-	-	1851.2

[a] Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981.

[b] Includes troll, handline, and sunken gillnet (1968 only).

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

Table 5.3. Sablefish trap LPUE (kg/trap) estimates (nominal and standardized) for the three major areas, 1978-1986.

	Vancouver Island		Queen Charlotte Sd.		Queen Charlotte Is.	
Year	nom.	stand.	nom.	stand.	nom.	stand.
1978	25.2	-	11.6	-	20.1	-
1979	14.1	12.0	14.0	22.7	20.9	17.5
1980	15.0	16.8	18.5	15.8	13.5	13.8
1981	10.3	9.9	17.9	18.0	18.5	19.2
1982	11.8	15.7	16.6	19.1	24.8	24.7
1983	13.7	11.1	17.0	16.5	17.9	18.9
1984	11.7	13.4	14.9	14.9	12.7	13.7
1985	15.2	15.6	20.3	17.4	19.6	18.2
1986	10.8	10.3	20.2	20.3	16.4	16.8

Table 5.4 Estimates of numbers of sablefish (X 10^3) at age 5 for the 1977 year-class based on Virtual Population Analysis runs at varying levels of Terminal F and natural mortality (M).

		Natural mortality (M)		
		0.05	0.1	0.2
Terminal F	0.05	2532	3129	5177
	0.1	2532	3140	5259
	0.2	2550	3149	5192

Table 5.5. Catch at age in numbers for sablefish from 1979-1985.

	Year						
Age	1979	1980	1981	1982	1983	1984	1985
4	1843	9301	112774	55193	62099	119293	28943
5	1843	13707	44390	172902	80498	184255	88206
6	1843	29372	27594	73779	317394	178349	195707
7	1843	37204	35992	41113	86248	287013	290804
8	1843	37204	16796	46745	37949	47245	237053
9	1843	42589	23395	52377	34499	34253	88206
10	22111	44058	29393	40550	55199	24804	22051
11	31324	63150	31193	61389	27599	25985	16539
12	40537	74409	48589	47872	50599	11811	4135
13	35010	84199	37191	51251	35649	23622	4135
14	73705	66576	40191	39987	45999	15355	17917
15	57121	58254	44390	55757	48299	16536	11026
16	62649	73430	37791	30976	28749	9449	4135
17	95816	59233	32992	22528	40249	7087	2756
18	82918	49443	26994	26470	26449	2362	5513
19	90288	46016	27594	19149	31049	14173	2756
20	75547	43568	21595	19149	29899	3543	5513
21	86603	43079	23994	19712	25299	2362	2756
22	71862	31330	21595	9011	21850	1181	1378
23	70019	19581	23395	10138	18400	3543	1378
24	68177	17134	16796	8448	14950	1181	1378
25	36852	17134	8998	10701	4600	1181	1378
26	38695	18602	10797	5632	6900	2362	1378
27	23954	11259	5999	8448	3450	2362	1378
28	23954	12728	8398	2253	3450	1181	1378
29	5528	6364	4799	2816	4600	1181	1378
30	11056	11259	5399	2253	1150	1181	1378
31	9213	6364	1800	563	2300	1181	1378
32	3685	2448	4799	1126	4600	1181	1378
33	7370	2937	1800	1690	1150	1181	1378
34	1843	2937	1800	1126	1150	1181	1378
35	5528	1469	5399	563	1150	1181	1378

Table 5.6. Annual estimates of sablefish numbers at age from Virtual Population Analysis (M=0.1, Terminal F=0.1).

Age	Year 1979	1980	1981	1982	1983	1984	1985
5	336009	337610	974893	3140424	3225155	2885651*	2208021*
6	300644	302869	292926	837703	2676092	2832144	2435020*
7	223546	268805	245854	237924	685853	2124555	2389954
8	386994	199821	207271	188951	177040	539511	1656466
9	291536	348859	145461	171405	126011	123517	441715
10	348967	260656	275824	108952	104844	81264	79238
11	324870	294477	193483	222258	60022	42703	49766
12	355669	263744	207354	144921	142686	28062	14011
13	292341	284242	168762	141822	85387	81522	14217
14	311807	231737	178039	117742	79696	43258	51251
15	289328	212933	146119	122873	69003	28798	24505
16	253388	206598	137349	89936	58381	16937	10554
17	267109	169036	117047	88338	51789	25457	6429
18	241582	150224	96673	74899	58464	9195	16293
19	227062	141005	88511	61769	42904	28037	6061
20	204844	120321	83831	54174	37795	9767	11956
21	189874	113394	67553	55105	31027	6111	5478
22	160817	89720	61479	38270	30984	4440	3280
23	136804	77762	51661	35080	26152	7417	2913
24	141226	57376	51749	24569	22066	6345	3359
25	99329	63625	35728	31044	14156	5941	4620
26	90207	54815	41130	23776	17872	8416	4238
27	78475	45325	32134	26891	16231	9591	5386
28	76835	48056	30164	23301	16276	11448	6411
29	56166	46745	31531	19306	18916	11475	9283
30	49720	45580	36083	24070	14838	12737	9213
31	32438	34689	30422	27545	19707	12270	10428
32	18525	20598	25316	25753	24389	15658	9962
33	84794	13213	16348	18389	22134	17751	13036
34	21812	69424	9218	13077	15055	19001	14977
35	60577	18038	59765	6648	10814	12535	16038

*Subject to error

Table 5.7. Annual estimates of sablefish fishing mortality rates (F) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year						
Age	1979	1980	1981	1982	1983	1984	1985
5	0.00	0.04	0.05	0.06	0.03	0.07*	0.04*
6	0.01	0.11	0.11	0.10	0.13	0.07	0.09*
7	0.01	0.16	0.16	0.20	0.14	0.15	0.14
8	0.00	0.22	0.09	0.31	0.26	0.10	0.16
9	0.01	0.13	0.19	0.39	0.34	0.34	0.24
10	0.07	0.20	0.12	0.50	0.80	0.39	0.34
11	0.11	0.25	0.19	0.34	0.66	1.01	0.43
12	0.12	0.35	0.28	0.43	0.46	0.58	0.37
13	0.13	0.37	0.26	0.48	0.58	0.36	0.36
14	0.28	0.36	0.27	0.43	0.92	0.47	0.46
15	0.24	0.34	0.39	0.64	1.30	0.90	0.64
16	0.30	0.47	0.34	0.45	0.73	0.87	0.53
17	0.48	0.46	0.35	0.31	1.63	0.35	0.59
18	0.44	0.43	0.35	0.46	0.63	0.32	0.44
19	0.54	0.42	0.39	0.39	1.38	0.75	0.64
20	0.49	0.48	0.32	0.46	1.72	0.48	0.66
21	0.65	0.51	0.47	0.48	1.84	0.52	0.75
22	0.63	0.45	0.46	0.28	1.33	0.32	0.58
23	0.77	0.31	0.64	0.36	1.32	0.69	0.68
24	0.70	0.37	0.41	0.45	1.21	0.22	0.56
25	0.49	0.34	0.31	0.45	0.42	0.24	0.37
26	0.59	0.43	0.32	0.28	0.52	0.35	0.42
27	0.39	0.31	0.22	0.40	0.25	0.30	0.31
28	0.40	0.32	0.35	0.11	0.25	0.11	0.26
29	0.11	0.16	0.17	0.16	0.30	0.12	0.17
30	0.26	0.30	0.17	0.10	0.09	0.10	0.17
31	0.35	0.21	0.07	0.02	0.13	0.11	0.15
32	0.24	0.13	0.22	0.05	0.22	0.08	0.16
33	0.10	0.26	0.12	0.10	0.05	0.07	0.12
34	0.09	0.05	0.23	0.09	0.08	0.07	0.10
35	0.10	0.09	0.10	0.09	0.12	0.10	0.09

*Subject to error

Table 5.8. Annual estimates of sablefish total mortality rates (Z) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year						
Age	1979	1980	1981	1982	1983	1984	1985
4	0.10	0.11	0.13	0.11	0.12	0.15*	0.12*
5	0.10	0.14	0.15	0.16	0.13	0.17	0.14*
6	0.11	0.21	0.21	0.20	0.23	0.17	0.19
7	0.11	0.26	0.26	0.30	0.24	0.25	0.24
8	0.10	0.32	0.19	0.41	0.36	0.20	0.26
9	0.11	0.23	0.29	0.49	0.44	0.44	0.34
10	0.17	0.30	0.22	0.60	0.90	0.49	0.44
11	0.21	0.35	0.29	0.44	0.76	1.11	0.53
12	0.22	0.45	0.38	0.53	0.56	0.68	0.47
13	0.23	0.47	0.36	0.58	0.68	0.46	0.46
14	0.38	0.46	0.37	0.53	1.02	0.57	0.56
15	0.34	0.44	0.49	0.74	1.40	1.00	0.74
16	0.40	0.57	0.44	0.55	0.83	0.97	0.63
17	0.58	0.56	0.45	0.41	1.73	0.45	0.69
18	0.54	0.53	0.45	0.56	0.73	0.42	0.54
19	0.64	0.52	0.49	0.49	1.48	0.85	0.74
20	0.59	0.58	0.42	0.56	1.82	0.58	0.76
21	0.75	0.61	0.57	0.58	1.94	0.62	0.85
22	0.73	0.55	0.56	0.38	1.43	0.42	0.68
23	0.87	0.41	0.74	0.46	1.42	0.79	0.78
24	0.80	0.47	0.51	0.55	1.31	0.32	0.66
25	0.59	0.44	0.41	0.55	0.52	0.34	0.47
26	0.69	0.53	0.42	0.38	0.62	0.45	0.52
27	0.49	0.41	0.32	0.50	0.35	0.40	0.41
28	0.50	0.42	0.45	0.21	0.35	0.21	0.36
29	0.21	0.26	0.27	0.26	0.40	0.22	0.27
30	0.36	0.40	0.27	0.20	0.19	0.20	0.27
31	0.45	0.31	0.17	0.12	0.23	0.21	0.25
32	0.34	0.23	0.32	0.15	0.32	0.18	0.26
33	0.20	0.36	0.22	0.20	0.15	0.17	0.22
34	0.19	0.15	0.33	0.19	0.18	0.17	0.20
35	0.20	0.19	0.20	0.19	0.22	0.20	0.19

Table 5.9. Annual exploitation rates by age for sablefish from Virtual Population Analysis (M=0.1, Terminal F=0.1).

	Year						
Age	1979	1980	1981	1982	1983	1984	1985
5	0.01	0.04	0.05	0.06	0.02	0.06*	0.04*
6	0.01	0.10	0.09	0.09	0.12	0.06	0.08*
7	0.01	0.14	0.15	0.17	0.13	0.14	0.12
8	0.00	0.19	0.08	0.25	0.21	0.09	0.14
9	0.01	0.12	0.16	0.31	0.27	0.28	0.20
10	0.06	0.17	0.11	0.37	0.53	0.31	0.28
11	0.10	0.21	0.16	0.28	0.46	0.61	0.33
12	0.11	0.28	0.23	0.33	0.35	0.42	0.30
13	0.12	0.30	0.22	0.36	0.42	0.29	0.29
14	0.24	0.29	0.23	0.34	0.58	0.35	0.35
15	0.20	0.27	0.30	0.45	0.70	0.57	0.45
16	0.25	0.36	0.28	0.34	0.49	0.56	0.39
17	0.36	0.35	0.28	0.26	0.78	0.28	0.43
18	0.34	0.33	0.28	0.35	0.45	0.26	0.34
19	0.40	0.33	0.31	0.31	0.72	0.51	0.45
20	0.37	0.36	0.26	0.35	0.79	0.36	0.46
21	0.46	0.38	0.36	0.36	0.82	0.39	0.50
22	0.45	0.35	0.35	0.24	0.71	0.27	0.42
23	0.51	0.25	0.45	0.29	0.70	0.48	0.47
24	0.48	0.30	0.32	0.34	0.68	0.19	0.41
25	0.37	0.27	0.25	0.34	0.32	0.20	0.30
26	0.43	0.34	0.26	0.24	0.39	0.28	0.33
27	0.31	0.25	0.19	0.31	0.21	0.25	0.26
28	0.31	0.26	0.28	0.10	0.21	0.10	0.21
29	0.10	0.14	0.15	0.15	0.24	0.10	0.15
30	0.22	0.25	0.15	0.09	0.08	0.09	0.15
31	0.28	0.18	0.06	0.02	0.12	0.10	0.13
32	0.20	0.12	0.19	0.04	0.19	0.08	0.14
33	0.09	0.22	0.11	0.09	0.05	0.07	0.11
34	0.08	0.04	0.20	0.09	0.08	0.06	0.09
35	0.09	0.08	0.09	0.08	0.11	0.09	0.09

Table 5.10. Annual estimates of sablefish numbers in stock, numbers landed, exploitation rates, mean F and Z values for ages 5-35, from Virtual Population Analysis (M=0.1, Terminal F=0.1).

Year	Nos. in stock	Nos. landed	Exploitation rate	Mean F	Mean Z
1979	6327819	1142423	0.18	0.28	0.38
1980	5681977	1036338	0.18	0.28	0.38
1981	7719588	784622	0.10	0.25	0.35
1982	9808445	941667	0.10	0.29	0.39
1983	11240117	1153425	0.10	0.62	0.72
1984	11631421	1028755	0.09	0.33	0.43
1985	10917291	1047443	0.10	0.34	0.44

Table 5.11. Projected yields (t) of sablefish for 1988 from forward simulations (F=0.205, 0.150, and 0.1025), using numbers at age from VPA conducted at varying levels of future constant recruitment.

		Natural mortality	
	Recruitment	0.05	0.1
F=.205	Low	2732	2521
	Aug.	4501	4522
F=.150	Low	2046	3366
	Aug.	1888	3380
F=.1025	Low	1427	2345
	Aug.	1316	2352

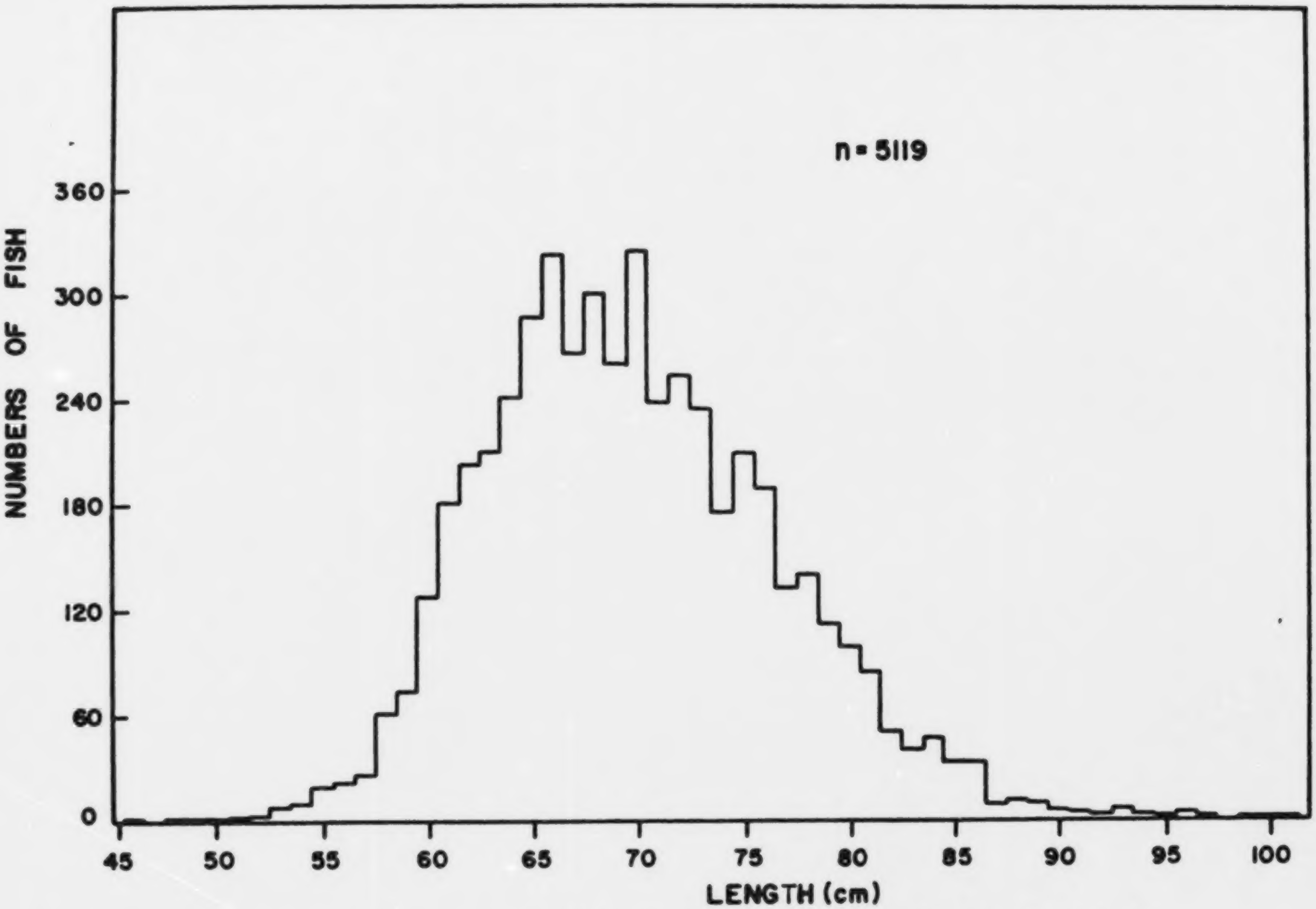

Fig. 5.1a. Length frequency of tagged sablefish off the Queen Charlotte Islands during 1977.

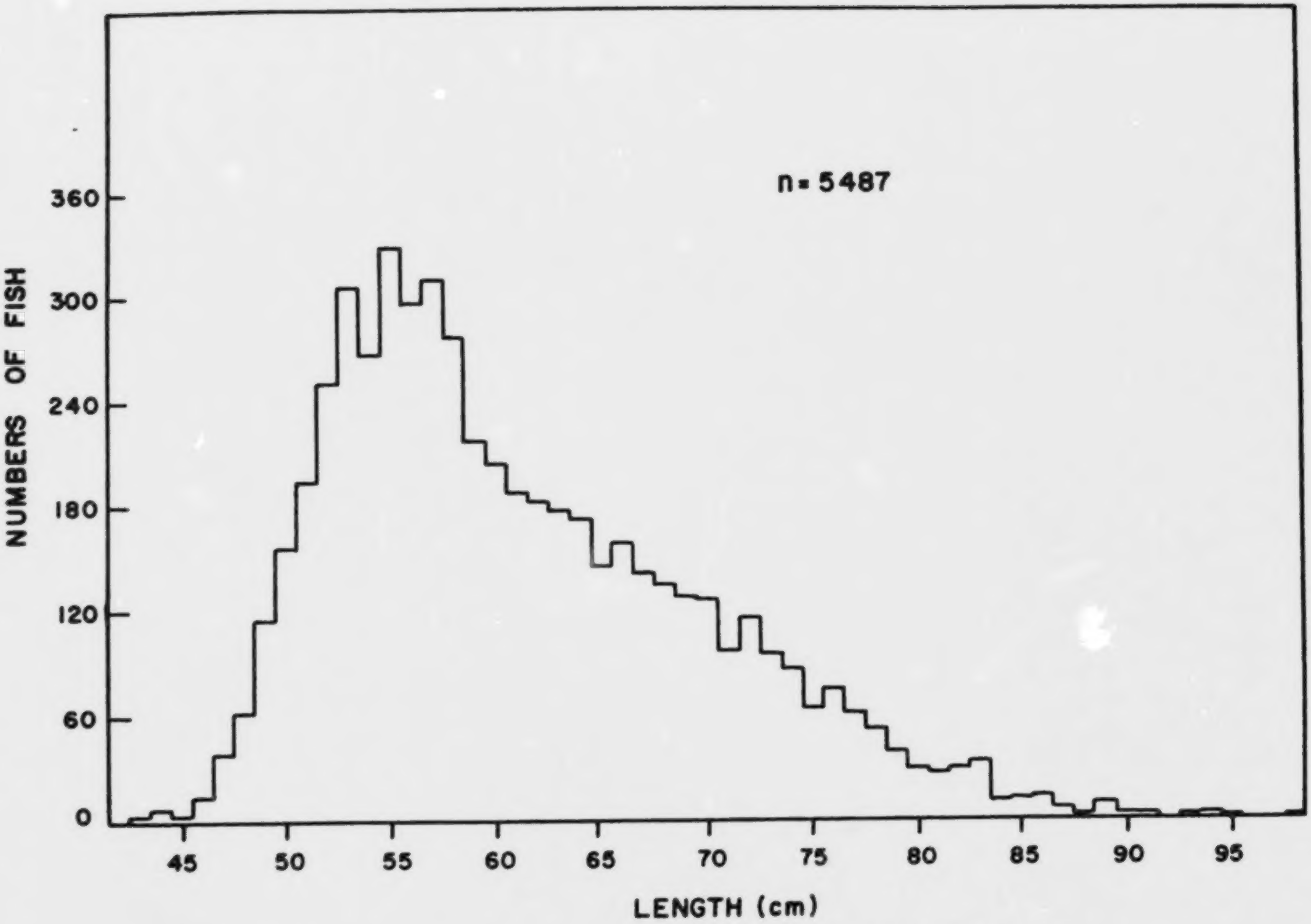

Fig. 5.1b. Length frequency of tagged sablefish off Vancouver Island during 1977.

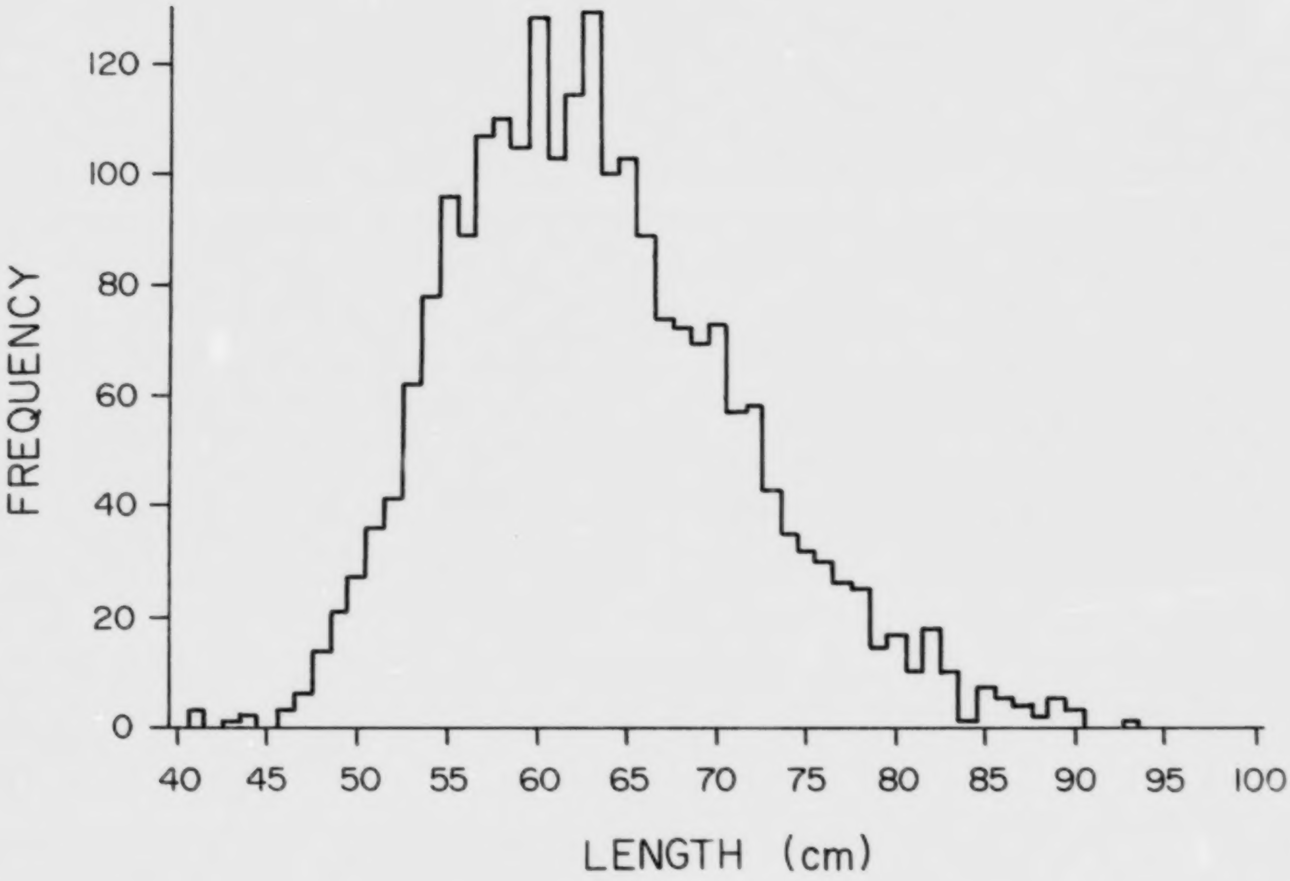

Fig. 5.1c. Length frequency of sablefish captured off the west coast of Vancouver Island during November 1986.

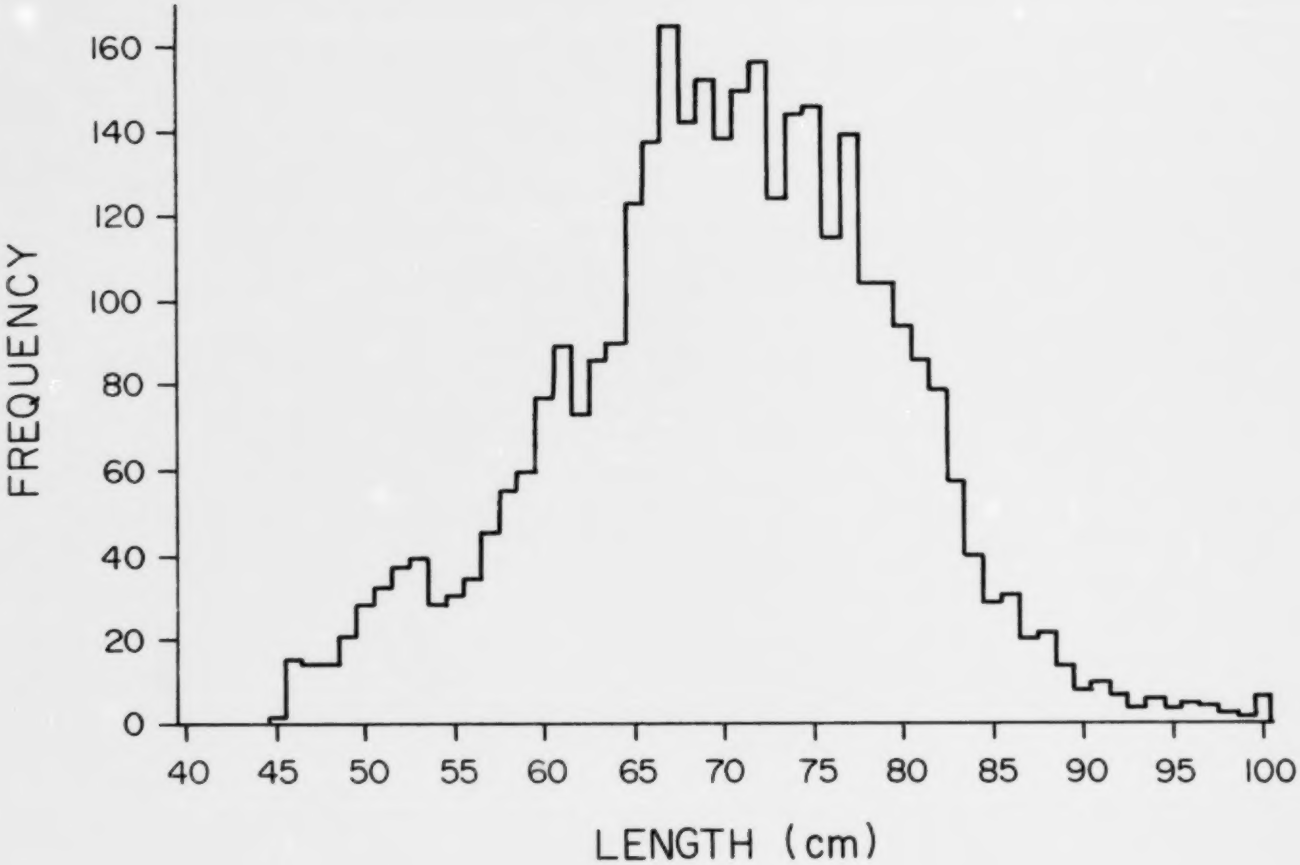

Fig. 5.1d. Length frequency of sablefish captured off the west coast of the Queen Charlotte Islands during November 1986.

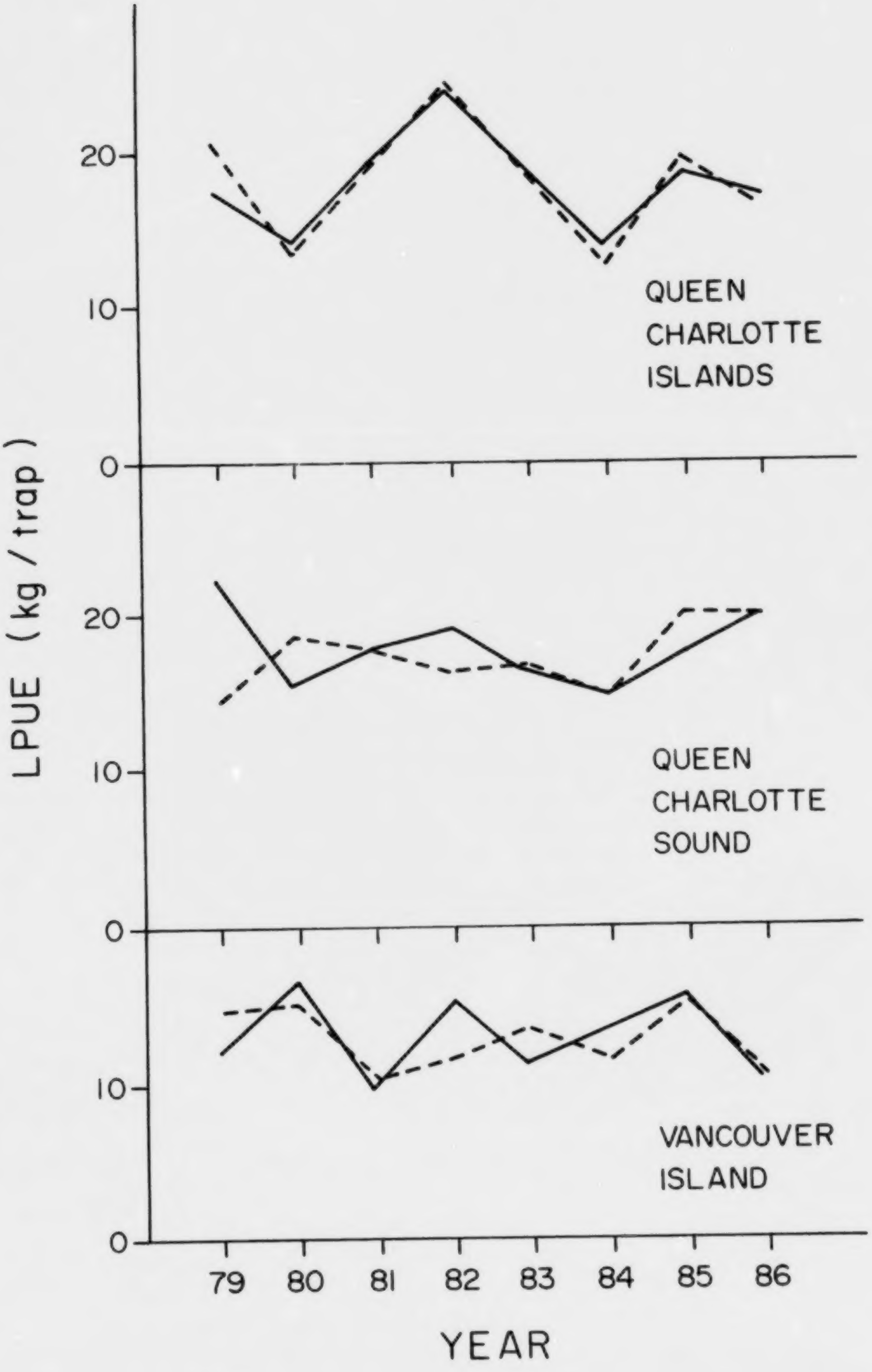

Fig. 5.2. Nominal (---) LPUE vs Standardized (——) LPUE estimates by major fishing area, 1979-1986.

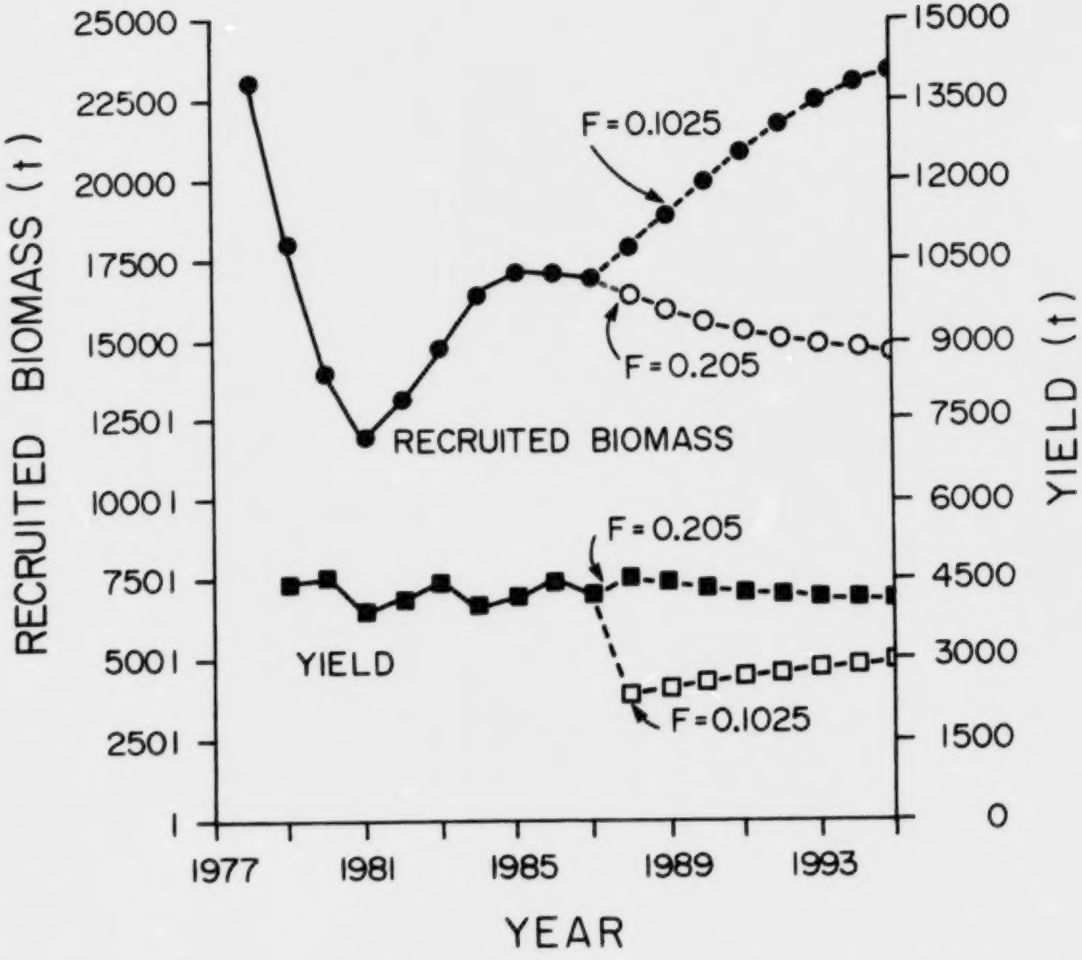

Fig. 5.3. Forward simulation of sablefish recruited biomass and yield at fishing rates (F) of 0.205 and 0.1025, assuming constant average recruitment.

6.0 PACIFIC HAKE

by W. Shaw, M. W. Saunders and
Anne Babcock Hollowed

6.1. Coastwide

Yield options are not proposed on a coastwide basis.

6.2. Strait of Georgia

6.2.1. Introduction

Pacific hake are the most abundant resident fish in the Strait of Georgia. Exploitation of the resident stocks has been increasing since the inception of the fishery in 1978. The proximity of the stocks to land-based processing, absence of the parasite Kudoa paniformes which is responsible for the rapid degradation of the flesh found in offshore Pacific hake, and the potential for harvesting roe from the large spawning concentration has made this an increasingly important fishery.

The 1988 assessment is based on results from catch at age analysis incorporated into a forward simulation model (Tyler 1982) to project hake biomass and yield from 1979 to 1997.

6.2.2. Landing statistics

During 1986, the fishery landed a total of 5031 t from the Strait of Georgia, an increase of 1.1% from the 1985 landings (Table 6.1). Approximately 35.1% and 50.5% of the total was landed during the first and second quarter respectively. Prior to 1986 most of the catch came from Minor Area 17. However in 1986 exploitation shifted from Minor Area 17 to Minor Areas 29, for a total 2296 t (45.6% of the total), and Minor Area 14 for a total of 1209 t (24.0% of the total).

6.2.3. General biological information

Biological data collected in 1986 indicates a small change in the size composition from previous years. The fishery continues to be supported by strong year-classes. The 1978 and 1981 year-classes contributed 17% and 16% respectively, to the fishery.

LPUE has increased substantially in 1986 from 4.448 t/hr in 1985 to 7.450 t/hr (Table 6.2).

6.2.4. Condition of the stock

The approach taken in this assessment is similar to that reported in the 1985 assessment for sablefish (McFarlane et al. 1985). A forward simulation model was used to project hake biomass and yield from the available data in 1979 to 1986 and then simulated forward from 1987 to 1997. The numbers at age used as the starting vector for the forward simulation were calculated using Virtual Population Analysis (VPA) (Gulland 1983).

The catch-at-age data used in the VPA are presented in Table 6.3. The catch-at-age was calculated as the ratio of number at age to weight at age in the age sample multiplied by the total catch. The weight at age in the sample was the sum of the weights of individual fish determined from length-weight relationships for males and females in the appropriate quarter (Table 6.4).

The VPA was run using eight years of age composition data, 1979-1986, using several estimates of instantaneous natural mortality (M) and terminal F to investigate the sensitivity of the analysis to these starting parameters. As discussed by Gulland (1983), the numbers at age for the younger age-groups are not drastically affected by the terminal F value, however, the estimated rate of natural mortality is critical. At each level of M, the numbers at age differ by less than eight percent over the range of terminal F's (0.05 to 0.4) while, at each terminal F level, the numbers at age for each natural mortality rate differ by a factor of 6 over the range of M=0.1-0.3 (Table 6.5). The rate of natural mortality (M) is reported to range between 0.16 and 0.29 (McFarlane et al. 1983). In the VPA runs a natural mortality of M=0.23 was used representing a midpoint in the range. A terminal F value of F=0.35 was used which was the average of the mean terminal F's in the older age classes which resulted in a similar biomass estimate for 1981 as compared to the results by Thompson and McFarlane (1982).

The numbers at age in the population, fishing mortality rates (F), total mortality rates (Z) and exploitation rates from the VPA using M=0.23, F=0.35 are presented in Tables 6.6, 6.7, 6.8, and 6.9 respectively, with totals by year reported in Table 6.10.

A general forward simulation model (Tyler 1982) was adapted for Pacific hake and was used to investigate constant catch and variable effort management scenarios. For the constant catch model forward projections were run with the numbers of age for 1979 from VPA results at different levels of M. Catches from 1979 to 1987 were included and numbers recruiting at age 2 were taken from the VPA up to 1986. Beyond 1986, recruitment was assumed to be constant and runs using low, average and high recruitment from the VPA were conducted. The recruitment values used are presented in Table 6.11. The trends in yield and biomass at three plausible rates of mortality are presented in Figure 6.1. Biomass has been increasing from 1979 to 1983 and has decreased slightly through to 1987. The biomass in 1981 ranges from 80 to 160 thousand t using 3 levels of natural mortality. These results compare favorably with fishery independent biomass estimates of 85-130 thousand t (Thompson and McFarlane 1982) and 40-150 thousand t (Kieser 1983). The biomass in 1987 is estimated to be between 98 and 130 thousand t. Under the constant catch model long term yields of 8000 t, 11,000 t and up to 16,000 t (M=0.16, 0.23, and 0.29, respectively) are sustainable assuming low recruitment.

For the variable catch model a yield per recruit analysis was conducted to determine the optimal F values ($F_{0.1}$). For the 3 levels of M (0.16, 0.23 and 0.29) the $F_{0.1}$ values determined are 0.19, 0.24 and 0.29 respectively. Each level of M and $F_{0.1}$ was substituted into the forward simulation model and run forward from 1986 using the levels of recruitment listed in Table 6.11. The projected yields for 1988 at varying levels of recruitment and M are presented in Table 6.12.

6.2.5. Yield options

Yield options are proposed under two management options, constant and variable yield. The yield options under constant yield are levels that should be sustainable over the long run working to the goal of providing a steady fishery. Under the variable catch option the goal is to optimize the yield per recruit. Yields available will likely vary considerably from year to year.

The risk associated with the harvest ranges is a function of the sensitivity of the entire analysis to the rate of natural mortality (M). In the case of variable catch the risk, in addition to M, is a function the inability to predict the numbers recruiting at age 2 in 1988. In light of the precautions outlined above for the variable yield scenario, the resulting sustainable yield options are based on the lower level of mortality.

Constant yield	- Low risk sustainable	- 8000 t
	- Sustainable	- 11000 t
	- High risk sustainable	- 16000 t
Variable yield	- Low risk sustainable	- 16000 t
	- Sustainable	- 19000 t
	- High risk sustainable	- 24000 t

6.3 West Coast Vancouver Island

6.3.1 Introduction

Offshore Pacific hake (Merluccius productus) are a highly migratory fish that range from southern California to Queen Charlotte Sound. Hake are present in the Canadian zone from late spring until late fall when they migrate south to spawn off California. The portion of the stock in Canadian waters is composed predominantly of larger, older females.

Since 1968, more Pacific hake have been landed than any other species in the groundfish fishery on Canada's west coast. Prior to 1977 the USSR caught the major percentage of hake in the Canadian zone with Poland and Japan accounting for much smaller quantities. Since 1977, and the declaration of the 200 mile extended fishing zone, the fishery has been divided into domestic, joint venture, and foreign operations. These are the most rapidly developing fisheries on Canada's west coast.

6.3.2 Landing statistics

Coastwide landings of Pacific hake have increased from 111.5 thousand t in 1985 to 210.6 thousand t in 1986 (Table 6.13). Landings by all nations in the Canadian zone were 55,652 t in 1986, up considerably from 24,962 t in 1985 (Table 6.14). The increase primarily is a result of participation by the USSR in 1986 after a year's absence in 1985. As in the past, most of the catch was sold directly to foreign processing vessels. Canadian landings from joint venture fisheries with Russian and Polish fishermen increased to 30,136 t in 1986 from 13,237 t in 1985. Domestic landings reported during 1986 totalled 1,774 t up from 1,192 t in 1985 (Table 6.14).

The accuracy of reported landings continues to be suspect. Landing figures up to and including 1986 were dependant on the reliability of foreign factory production figures and on the accuracy of product to round conversion factors. Efforts to verify landings through direct observation have been hampered by decreasing coverage and the inexperience of the observers employed. Checking of the trans-shipped product has also proved difficult. In 1987, however, an intensive observer program was instituted and as a consequence landing estimates used in future assessments should be more reliable.

6.3.3 General biological information

Biological data collected in 1986 indicate little change in the size composition of the offshore hake stock in the Canadian zone. The fishery continues to be supported by a series of strong year-classes (Fig. 6.2). In particular, the 1980 and 1977 year-classes contributed 55.0% and 19.8%, respectively to the 1986 catch. The U.S. fishery was supported by the strong 1980 and 1984 year-classes.

In a fishery dominated by a small number of year-classes it is desirable to have the ability to forecast the relative strength of recruitment based on pre-recruit abundance. Measures of catch per unit effort and percent occurrence of 0-age hake in mid-water trawl surveys conducted by the California Department of Fish and Game off the California coast over the last 20 years appear be good indicators (Hollowed et al. in prep). Figure 6.3 presents the two indices and the abundance of three-year-olds obtained from cohort analysis (Section 6.3.4). The strong 1970, 1973, 1977, and 1980 year-classes are identifiable.

The surveys indicate that the 1984 and 1986 year-classes are average (Fig. 6.3). In addition, catch-at-age data from the fisheries in 1985 and in 1986 as well as results from the 1986 triannual NWAFC trawl/hydroacoustic survey indicate that the 1984 year-class is strong.

6.3.4 Condition of the stock

During 1982 and 1983 cooperative research programs initiated through the Canada-U.S. International Groundfish Committee were conducted to examine the relationships between Canadian and U.S. fisheries for hake with the goal of developing joint management alternatives. This work culminated with the application of a stochastic model developed by Getz and Swartzman (1981) to Pacific hake (Swartzman et al. 1983; McFarlane and Francis 1985; Francis et al. 1984). Francis (1985) simplified the management models of Swartzman et al. (1983) and Francis et al. (1984) and the resulting model was used to evaluate the status of offshore hake production in 1987 and to provide estimates of future catch for effective management of the stock.

In 1987 a cooperative research link was re-established with U.S. scientists. A working group was formed and has drawn up priority areas of joint research to be conducted through 1988. Canadian research in 1987 focused on obtaining and examining the simplified model currently in use. The material summarized in this document is presented in more detail in Hollowed et al. (in prep.).

In this assessment the age-structured simulation model, utilizing information on mortality, growth, abundance (from cohort analysis) and recruitment, was used to produce long-term estimates of hake production and projected yields for 1988-90.

A natural mortality rate of 0.2 over all ages was used in cohort analysis and in the forward simulations.

Catch-at-age for 1973-78 and from 1980-85 are from Hollowed and Francis (1986). Estimates for 1979 were updated to reflect corrections for ageing error made to the age composition of the catch. Estimates for 1986 in the U.S. were calculated using a procedure developed by Kimura (in prep.).

Catch-at-age for 1986 in the Canadian zone was calculated by using the ratio of number at age to the weight at age in the age sample times the total catch. The weight-at-age in the sample was the sum of the weights from individual fish derived from length-weight relationships for males and females sampled in 1986. Canada and U.S. catches-at-age were summed to provide coastwide estimates (Table 6.15).

Cohort analysis was run using 14 years of catch-at-age data, 1973 to 1986. The cohort analysis was developed by Francis (1983) and uses the analytic formulation of Pope (1972) and Tomlinson (1970). Terminal F values were varied to provide the best least squares fit to the numbers at age derived from the NWAFC hydroacoustic/trawl surveys. The estimates of numbers at age from the cohort analysis and NWAFC survey and fishing mortality rates by age are presented in Table 6.15.

Estimates of annual mean length-at-age and mean weight-at-age were calculated using 1975-1986 data from the National Marine Fisheries Service (NMFS) U.S. Observer Program.

The age-structured model is a modification of Walters (1969) generalized model for fish populations. The model has a stochastic as well as a deterministic form. Recruitment is assumed to be a function of temperature at the time of spawning. Bailey (1981) showed hake recruitment to be inversely correlated to wind driven Ekman transport on the spawning ground at the time of spawning. He further reasoned that offshore transport was positively correlated with the level of upwelling which, in turn, was negatively correlated with sea surface temperature. Hence, years of 'cold' water temperatures were assumed to be years of low larval survival and conversely years of 'warm' water temperatures were assumed to be years of higher larval survival. The time series of average January-March sea surface temperatures in Los Angeles Bight are presented in Figure 6.4.

The model is run in two modes, equilibrium and look-ahead. The equilibrium model utilizes a theoretical unfished population and is run over 1000 years to establish optimal levels of effort where yield is maximized. The temperatures from 1943 to 1982 were cycled through the model 25 times to make up the 1000-year run. Recruitment was considered to be a function of temperature alone. In warm years (>15 deg) the mean warm year recruitment (0.971 billion) and in cold years (<15 deg) the mean cold year recruitment was used (.206 billion). There is no apparent stock recruit relationship within the range of information available. In light of this, optimum effort was defined as the effort level that produced a spawner biomass above the lowest observed level (.3193 million t) 90% of the time. A summary of parameter values used in the 1000-year runs is presented in Table 6.16. Once the optimum effort level was determined using the deterministic version additional runs were made using the stochastic version. Stochasticity was incorporated in recruitment as a log-normal random variable with mean equal to the corresponding cold or warm year mean recuitment and variance equal to the observed coefficient of variation in recruitment for the respective temperature condition.

Runs were conducted under two possible management scenarios, constant effort and variable effort. The variable effort strategy is similar to that described by Shuter and Koonce (1985) as one which greatly reduces the risk of stock collapse when compared with a constant catch or constant effort. Effort in a given year was calculated as follows:

$$f_i = \text{effort in year } i$$
$$= f\,o_p\,(SB_i\ /SB\,o_p)$$

Where,

$f\,o_p$ = optimal effort
$SB\,o_p$ = mean observed spawner biomass level
SB_i = spawner biomass in year i

A summary of the equilibrium run results is presented in Table 6.17. The maximum average annual surplus production of the stock ranges from 196 and 185 thousand t for the variable and constant effort scenarios respectively, using the deterministic form of the model and from 182 and 165 thousand t for the variable and constant effort respectively using the stochastic form. The stochastic version produces slightly lower estimates of average yield from substantially lower values of F_{opt}.

The optimal levels of effort and biomass were then used in look ahead simulations to make projections of future yields. The starting population in 1986 are numbers at age from cohort analysis. Recruitment at age three of the 1984 and 1986 year-classes was assumed to be strong while recruitment from the 1985 and 1987 year-classes was assumed to be of average strength (mean recruitment for warm years excluding the strong year-classes).

The results of 1988-1990 catch projections under various policy options are presented in Table 6.18. The first two show the results of the application of the constant effort and variable effort and policies derived using the optimum fishing effort determined in the 1000-year runs of the stochastic version of the model. Given the variability observed in recruitment, the effort levels from the stochastic runs were chosen over the deterministic levels.

Under a constant effort scenario the projected yield for 1988 is 327 thousand t while under variable effort management a yield of 587 thousand t is projected. Average biomass (Table 6.18) and the resulting projected yield decrease substantially in 1989 and 1999 applying the variable and constant effort options.

Alternative options of constant effort and constant catch were also explored (Table 6.18). The yields presented provide only slightly lower mean and total catches over the three years to 1990, provide the same level of protection to the spawning stock as the variable effort algorithm (reduces the spawning stock no lower than 0.559 thousand t by the beginning of 1991), and reduce the drop in yield between years. At the levels of harvest projected to 1990, adequate biomass at ages greater than five years is maintained (Fig. 6.6), indicating that the Canadian fishery on older, larger fish will be sustained.

The analysis presented is conducted on a coastwide basis. A split stock model is under development which will facilitate exploration of the biological implications of varying harvest strategies on U.S. and Canadian components of the stock. Other areas of the assessment to be addressed by the Canada-U.S. working group include:

1. The growth parameters currently used are based on a long term mean. For future assessments year-specific growth information will be incorporated.
2. An in-depth evaluation of the catch-at-age methods.
3. A re-evaluation of the physical processes underlying recruitment.
4. Estimation of age-specific mortality rates

6.3.5 Yield Options

The yield options for the Canadian fishery are presented below with associated coastwide quotas in brackets. The Canada-U.S. split is based on the proportion of exploitable biomass in the Vancouver INPFC area. The proportion has ranged from 22.1 to 41.1 over the period 1977 to 1986, hence a mean value of 30 % was applied to the coastwide quotas to arrive at the Canadian allocation. It is recognized that the Vancouver INPFC area includes a small portion of the U.S. zone, however, movement and exchange of fish in the transboundary area is believed to be considerable and variable from year. Biomass estimates for this area from previous surveys are not available at present, although even with them the actual split in biomass between Canada and the U.S. will be a range open to debate.

The low risk levels of 98 thousand t are projected to be sustainable through 1990. At levels above this the sustainable yield in successive years decreases considerably. Risk reflects uncertainty in the assessment in particular with respect to predicting the strength of recruiting year-classes. At the higher yield levels the probability of seriously affecting the spawning biomass and hence stock collapse is greater.

Constant effort			
- low risk sustainable	98	(327)	thousand t
- high risk sustainable	147	(490)	thousand t
Variable effort			
- low risk sustainable (constant catch)	98	(325)	thousand t
- high risk sustainable	176	(587)	thousand t

Table 6.1. Pacific hake landings (t) for the second quarter and whole year for Minor Areas 14, 17 and 29, and Major Area 4B (Strait of Georgia) during 1977-1986.

	1977		1978		1979		1980		1981		1982		1983		1984		1985		1986	
Region	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr	Q_2	Yr
Minor Area																				
14	0	0	-	-	-	-	0	385	448	523	-	-	53	53	368	368	15	77	849	1209
17	-	-	0	1	484	484	-	-	76	182	1927	2420	2208	2240	805	1736	1700	3718	1073	1158
29	-	-	0	0	2	2	0	5	810	1434	0	12	0	11	544	951	67	982	618	2296
Major Area																				
4B	0	0	1	2	486	516	1	508	1364	2409	1927	2824	3078	3122	1717	3056	1827	4976	2540	5031

Table 6.2. Pacific hake landings, LPUE and effort from the Strait of Georgia (Major Area 4B), 1977-1986.

Year	Total catch (t)	LPUE[a] (t/hr)	Effort[b] (hr)
1977	0.04	0.00	0
1978	2	0.00	0
1979	516	10.207	51
1980	508	4.583	111
1981	2409	8.937	270
1982	2824	4.796	589
1983	3121	4.465	699
1984	4599	6.780	678
1985	4976	4.448	1119
1986	5031	7.450	675

[a] LPUE @ 25% qualification level.
[b] Effort = Total catch/LPUE.

Table 6.3. Catch in numbers (thousands) of Strait of Georgia Pacific hake at age proportioned from the age composition and used in the Virtual Population Analysis. The catch and age distribution of Pacific hake were from the commercial catch and from research surveys, respectively, in the Strait of Georgia from 1979-1986.

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1979	69	27	123	216	204	207	192	193	51	9	9	10	6
1980	78	480	268	369	168	223	134	179	101	0	22	0	0
1981	72	456	654	276	468	816	666	738	534	1013	114	96	42
1982	42	357	2216	1224	622	786	791	559	677	252	488	50	25
1983	3468	974	2296	2577	644	495	347	297	198	248	116	116	17
1984	38	488	1352	2780	4169	1578	939	789	676	488	188	75	150
1985	937	1478	1334	1082	1046	3317	1731	865	757	541	288	180	0
1986	38	1136	1742	1742	1250	1060	2461	2234	947	492	303	341	76

Table 6.4. Regression coefficients[a] used in length weight conversions[b] for Pacific hake in the Strait of Georgia by quarter and by sex.

		Males	Females
Quarter 1	a	0.0155	0.00560
	b	2.7412	3.02900
Quarter 2	a	0.1406	0.06190
	b	2.1103	2.33700
Quarters 3/4	a	1.0882	0.02586
	b	1.5712	1.96930

[a] McFarlane et al. 1983

[b] Wt (gm) = a (Fork length (cm))^b

Table 6.5. Estimates of numbers of Pacific hake at age 2 (x1000) in the Strait of Georgia in 1979 from virtual population analysis runs at varying levels of Terminal F (F) and natural mortality (M).

		Terminal F				
		0.05	0.1	0.2	0.3	0.4
Natural mortality (M)	0.1	43112	40338	37859	37318	36937
	0.2	106528	97178	90496	88379	85146
	0.23	140759	126968	117435	113918	113577
	0.3	273064	247299	224333	220370	211756

Table 6.6. Annual estimates of numbers at age of Pacific hake in the Strait of Georgia from Virtual Population Analysis (M=0.23, Terminal F=.35).

1979-86

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1979	112856	34735	20330	14508	8640	6584	2519	5009	499	378	463	11	200
1980	152282	88844	27344	16005	11309	6700	5037	1828	3792	351	293	361	0
1981	69929	119882	69941	21526	12411	8815	5110	3880	1298	2921	276	214	284
1982	94666	55050	94375	55060	16780	9431	6262	3471	2425	563	1426	119	85
1983	115694	74524	43337	73182	42696	12751	6791	4260	2254	1324	224	702	51
1984	142379	89117	58092	32347	55994	33282	9640	5092	3129	1616	829	77	457
1985	134811	112086	70156	45047	23291	40863	24955	6848	3353	1891	852	494	0
1986	3467	106127	87371	54686	34699	17581	29621	18335	4658	1999	1026	426	232

Table 6.7. Annual estimates of fishing mortality rates (F) of Pacific hake in the Strait of Georgia from Virtual Population Analysis (M=.23, Terminal F=.35).

1979-86

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1979	0.01	0.01	0.01	0.02	0.02	0.04	0.09	0.05	0.12	0.02	0.02	4.00	0.03
1980	0.01	0.01	0.01	0.02	0.02	0.04	0.03	0.11	0.03	0.01	0.09	0.01	0.07
1981	0.01	0.01	0.01	0.02	0.04	0.11	0.16	0.24	0.61	0.49	0.61	0.69	0.18
1982	0.01	0.01	0.02	0.02	0.04	0.10	0.16	0.20	0.37	0.69	0.48	0.63	0.39
1983	0.03	0.02	0.06	0.04	0.02	0.05	0.06	0.08	0.10	0.24	0.84	0.20	0.47
1984	0.01	0.01	0.02	0.10	0.09	0.06	0.11	0.19	0.27	0.41	0.29	7.98	0.45
1985	0.01	0.02	0.02	0.03	0.05	0.09	0.08	0.16	0.29	0.38	0.46	0.52	0.75
1986	0.01	0.01	0.02	0.04	0.04	0.07	0.10	0.15	0.26	0.32	0.40	2.00	0.45
Mean	0.01	0.01	0.02	0.04	0.04	0.07	0.10	0.15	0.26	0.32	0.40	2.00	0.35
C.V.	0.62	0.37	0.78	0.72	0.53	0.40	0.45	0.44	0.71	0.72	0.67	1.37	0.68

Table 6.8. Annual estimates of total mortality rates (Z) of Pacific hake in the Strait of Georgia from Virtual Population Analysis (M=.23, Terminal F=.35).

1979-86

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1979	0.24	0.24	0.24	0.25	0.25	0.27	0.32	0.28	0.35	0.25	0.25	4.23	0.26
1980	0.24	0.24	0.24	0.25	0.25	0.27	0.26	0.34	0.26	0.24	0.32	0.24	0.30
1981	0.24	0.24	0.24	0.25	0.27	0.34	0.39	0.47	0.84	0.72	0.84	0.92	0.41
1982	0.24	0.24	0.25	0.25	0.27	0.33	0.39	0.43	0.60	0.92	0.71	0.86	0.62
1983	0.26	0.25	0.29	0.27	0.25	0.28	0.29	0.31	0.33	0.47	1.07	0.43	0.70
1984	0.24	0.24	0.25	0.33	0.32	0.29	0.34	0.42	0.50	0.64	0.52	8.21	0.68
1985	0.24	0.25	0.25	0.26	0.28	0.32	0.31	0.39	0.52	0.61	0.69	0.75	0.98
1986	0.24	0.24	0.25	0.27	0.27	0.30	0.33	0.38	0.49	0.55	0.63	2.23	0.68
Mean	0.24	0.24	0.25	0.27	0.27	0.30	0.33	0.38	0.49	0.55	0.63	2.23	0.58
C.V.	0.03	0.02	0.07	0.10	0.08	0.09	0.13	0.17	0.37	0.42	0.43	1.23	0.41

Table 6.9. Annual exploitation rates (nos. caught/nos. in the stock) by age of Pacific hake in the Strait of Georgia from Virtual Population Analysis (M=0.23, Terminal F=0.35).

1979-86

	Age												
Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1979	0.00	0.00	0.01	0.01	0.02	0.03	0.08	0.04	0.10	0.02	0.02	0.93	0.03
1980	0.00	0.01	0.01	0.02	0.01	0.03	0.03	0.10	0.03	0.00	0.07	0.00	0.00
1981	0.00	0.00	0.01	0.01	0.04	0.09	0.13	0.19	0.41	0.35	0.41	0.45	0.15
1982	0.00	0.01	0.02	0.02	0.04	0.08	0.13	0.16	0.28	0.45	0.34	0.42	0.29
1983	0.03	0.01	0.05	0.04	0.02	0.04	0.05	0.07	0.09	0.19	0.52	0.17	0.34
1984	0.00	0.01	0.02	0.09	0.07	0.05	0.10	0.15	0.22	0.30	0.23	0.97	0.33
1985	0.01	0.01	0.02	0.02	0.04	0.08	0.07	0.13	0.23	0.29	0.34	0.36	0.00
1986	0.01	0.01	0.02	0.03	0.04	0.06	0.08	0.12	0.20	0.25	0.30	0.80	0.33

Table 6.10. Annual estimates of numbers in stock (x1000), numbers landed (x1000), exploitation rates, mean F and Z values (ages 2-14) of Pacific hake in the Strait of Georgia, from Virtual Population Analysis (M=.23, Terminal F=.35).

Year	Nos. in stock	No. landed	Exploitation rate	Mean F	Mean Z
1979	206732	1316	0.01	0.34	0.57
1980	314146	2022	0.01	0.04	0.27
1981	316487	5945	0.02	0.24	0.47
1982	339713	8089	0.02	0.24	0.47
1983	377790	11793	0.03	0.17	0.40
1984	432051	13710	0.03	0.77	1.00
1985	464647	13556	0.03	0.22	0.45
1986	360228	13822	0.04	0.30	0.53

Table 6.11. Numbers at age 2 of Pacific hake in the Strait of Georgia representing low average and high recruitment at varying levels of M from Virtual Population Analysis (Terminal F=0.35).

		Numbers at age 2 (x1000)
M = 0.16	Low	41,426
	Average	62,553
	High	108,229
M = 0.23	Low	69,929
	Average	103,260
	High	152,283
M = 0.29	Low	115,589
	Average	164,773
	High	256,040

Table 6.12. Projected 1988 yields (t) and biomass (t) at F_{opt}[a] for Pacific hake in the Strait of Georgia at varying levels of M and recruitment.

		Recruitment		
		Low	Average	High
	0.16	16,200 (74,500)	18,700 (87,300)	24,200 (115,000)
M	0.23	20,700 (72,700)	24,900 (88,600)	31,000 (112,000)
	0.29	31,200 (86,700)	37,500 (105,800)	49,300 (141,500)

[a] for M = 0.16 F_{opt} = 0.19
for M = 0.23 F_{opt} = 0.24
for M = 0.29 F_{opt} = 0.29

Table 6.13. Annual catches of offshore Pacific hake (1,000 t) in U.S. and Canadian waters by foreign, joint venture (JV), and domestic fleets.

	United States				Canada				Combined		
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Total	LPUE	Effort
1966	137.000	0.000	0.000	137.000	0.700	0.000	0.000	0.000	137.000	19.2	7.171
1967	168.699	0.000	8.963	177.658	36.713	0.000	0.000	36.713	214.371	36.0	5.951
1968	60.660	0.000	0.159	60.819	61.361	0.000	0.000	61.361	122.180	11.8	10.397
1969	86.187	0.000	0.093	86.280	93.851	0.000	0.000	93.851	180.131	18.5	9.726
1970	159.509	0.000	0.066	159.575	75.009	0.000	0.000	75.009	234.584	25.6	9.180
1971	126.485	0.000	1.428	127.913	26.699	0.000	0.000	26.699	154.612	17.5	8.842
1972	74.093	0.000	0.040	74.133	43.413	0.000	0.000	43.413	117.546	15.9	7.381
1973	147.441	0.000	0.072	147.313	15.125	0.000	0.001	15.126	162.439	23.8	6.752
1974	194.108	0.000	0.001	194.109	17.146	0.000	0.004	17.150	211.259	24.3	8.705
1975	205.654	0.000	0.002	205.656	15.704	0.000	0.000	15.704	221.360	19.0	11.646
1976	231.221	0.000	0.218	231.549	5.972	0.000	0.000	5.972	237.521	25.7	9.242
1977	127.013	0.000	0.489	127.502	5.191	0.000	0.000	3.453	130.955	30.9	4.244
1978	96.827	0.856	0.689	98.372	3.453	1.814	0.000	6.454	104.836	35.2	2.980
1979	114.909	8.834	0.937	124.680	7.900	4.233	0.302	12.435	137.115	26.0	5.276
1980	44.023	27.537	0.792	72.352	5.273	12.214	0.097	17.584	89.936	28.5	3.152
1981	70.365	43.556	0.839	114.760	3.919	17.159	3.283	24.361	139.121	28.3	4.915
1982	7.089	67.464	1.024	75.577	12.479	19.676	0.002	32.155	107.732	30.9	3.489
1983	0.000	72.100	1.050	73.150	13.117	27.657	0.000	40.774	113.924	-	-
1984	14.722	78.889	2.721	96.382	13.203	28.906	0.000	42.109	138.491	-	-
1985	49.853	32.033	4.636	86.522	10.533	13.237	1.192	24.962	111.484	-	-
1986	69.861	81.640	3.463	154.964	23.743	30.136	1.774	55.652	210.616		
MEAN				125.053				31.031	156.091		

Table 6.14. Total landing (t) of offshore hake by foreign and domestic fishery off Canada (Area 3C) during 1978-1986.

		Total landings (t)			
Year	Nations	National	Joint venture	Domestic	Total
1978	Poland	589	1,814		
	USSR	700	0		
	Japan	3,364	0		
	Total	4,653	1,814		6,467
1979	Poland	4,263	3,102		
	USSR	0	1,131		
	Japan	3,637	0		
	Total	7,900	4,233	302	12,435
1980	Poland	4,456	4,560		
	USSR	78	4,300		
	Japan	817	0		
	Greece	0	3,355		
	Total	5,351	12,214	96	17,661
1981	Poland	3,189	4,779		
	USSR	227	7,342		
	Japan	187	0		
	Greece	0	4,9827		
	Total	3,603	17,048	4,440	25,091
1982	Poland	10,357	10,222		
	USSR	0	9,391		
	Japan	2,237	0		
	Total	12,594	19,613	2	32,209
1983	Poland	13,177	13,464		
	USSR	0	14,192		
	Total	13,177	27,656	0	40,833
1984	Poland	13,203	9,214		
	USSR	0	19,692		
	Total	13,203	28,906	0	42,109
1985	Poland	10,533	13,237	1,192	
	Total	10,533	13,237	1,192	24,962
1986	Poland	15,604	13,494		
	USSR	8,138	16,642		
	Total	23,742	30,136	1,774	55,652

N.B. Catches reported in this fishery cannot be verified by weight tallies, as domestic catches are.

Table 6.15. Catch at age data for the cohort analysis, fishing mortality coefficients from the cohort analysis, and observed mean numbers-at-age for offshore Pacific hake from surveys.

Age	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
CATCH AT AGE DATA (millions)														
3	55.89	0.98	2.69	36.82	3.82	4.15	1.44	15.20	1.78	1.94	103.12	2.20	0.39	9.53
4	9.68	150.14	3.67	29.26	54.60	8.10	17.70	8.95	107.52	2.07	4.71	155.03	12.87	1.98
5	21.71	20.52	128.11	29.59	11.32	48.58	10.97	9.11	10.44	71.53	4.58	8.84	116.96	16.49
6	40.20	35.50	21.89	185.10	20.23	9.40	51.75	10.16	12.18	5.79	64.76	14.40	11.69	217.08
7	25.15	44.29	23.54	27.62	69.94	19.85	16.51	23.12	6.48	7.55	5.03	41.00	8.7	23.32
8	23.00	25.73	38.00	13.81	11.58	38.45	31.67	10.65	27.79	6.75	6.30	6.08	17.58	13.44
9	21.50	11.40	17.15	4.93	6.30	5.85	23.31	8.68	7.53	16.98	5.17	5.84	1.76	25.58
10	10.32	3.58	7.40	0.99	3.13	2.90	3.70	22.87	6.46	3.43	15.30	4.12	0.71	2.58
11	4.51	1.63	3.70	0.31	3.13	2.90	1.92	2.37	14.33	3.49	2.54	8.72	1.01	1.56
FISHING MORTALITY COEFFICIENTS														
3	.02957	.00280	.00912	.05182	.02544	.02068	.00998	.01452	.00477	.00467	.02915	.00907	.01543	.06759
4	.03456	.10352	.01303	.12944	.10119	.06911	.11489	.07929	.13483	.00682	.01396	.05582	.06710	.10139
5	.10318	.09542	.12064	.13678	.06762	.12295	.12584	.07968	.12513	.12477	.01865	.03274	.05435	.11490
6	.19621	.24407	.13945	.25586	.13056	.07352	.18635	.16431	.14536	.09459	.15886	.07500	.05523	.13519
7	.21381	.34396	.25339	.26198	.14481	.18279	.17853	.11869	.14986	.12612	.11136	.14291	.05554	.14870
8	.62177	.35265	.55967	.23156	.16676	.11059	.49231	.16731	.20426	.23013	.14725	.19062	.08396	.12166
9	.72353	.73595	.42131	.12758	.15697	.11884	.09061	.24061	.17103	.18528	.27683	.19787	.07745	.16898
10	.88207	.24561	1.87848	.03773	.11161	.10051	.10261	.12054	.28370	.10955	.25344	.37143	.03317	.15546
11	.33760	.32208	.40390	.34195	.16127	.14304	.08969	.08826	.10321	.24423	.11061	.24410	.14432	.09463

MEAN NUMBERS AT AGE

	1977		1980		1983		1986	
Age	Est	Obs	Est	Obs	Est	Obs	Est	Obs
3	150	90	1047	1581	3538	2728	141	82
4	540	508	113	128	337	45	20	19
5	167	41	114	90	245	26	144	142
6	155	61	62	73	408	330	1606	1607
7	483	573	195	265	45	31	157	158
8	69	70	64	79	43	32	110	114
9	40	44	36	206	19	29	151	146
10	28	28	190	88	60	45	17	16
11	19	19	27	58	23	17	16	17
Sum of squares	37,550		332,666		796,639		3,523	
Total	1,170,380							

Table 6.16. Parameter values used in 1000 year simulation runs of offshore Pacific hake.

N	Number of age classes	13
R	Number of years that recruitment is delayed after spawning	3
SBOPT	Optimum spawner biomass level (million t) set at mean observed spawner biomass	0.6373
SBMIN	Minimum spawning biomass (million mt)	0.3193
RW	Average warm year recruitment (billions)	0.971
RC	Average cold year recruitment (billions)	0.206
M	Natural mortality coefficient	0.2

	Age												
Parm.	3	4	5	6	7	8	9	10	11	12	13	14	15
Q	0.00360	0.01417	0.02012	0.03154	0.03756	0.08877	0.07864	0.07888	0.078888	0.07888	0.07888	0.07888	0.07888
C	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M	0.4098	0.5190	0.6105	0.6991	0.7898	0.8952	0.9683	1.0315	1.1162	1.2050	1.2190	1.2330	1.2360
I	0.520	0.446	0.354	0.282	0.224	0.178	0.141	0.112	0.089	0.071	0.056	0.045	0.036
PCIF	0.508	0.506	0.514	0.519	0.522	0.539	0.549	0.558	0.583	0.583	0.583	0.583	0.583

Q = Age specific catchability coefficient.
C = Proportion of mature females.
W = Average weight at age (kg).
I = Initial numbers at age used for managment runs (billions).
PCIF = Percentage of weight represented by females.

Table 6.17. Summary of the results from the 1000 year runs of the deterministic and stochastic versions of the offshore Pacific hake model under constant recruitment management policy.

Management policy	Y (CV) (thousand)	f (CV) (thousand d)	CPUE (t/d)	B (CV) (thousand t)	% years SB<CRIT	Minimum biomass (thousand t)	Fopt (thousand t)
Variable effort -Det	196 (36.0)	8.4 (25.2	23.3	923 (27.1)	10%	436	11.000
Stoch	182 (70.2)	5.2 (42.9)	34.9	1083 (47.3)	10%	376	5.830
Constant effort -Det	185 (29.3)	6.3 (0.0)	29.3	1048 (31.0)	10%	404	6.300
Stoch	165 (50.8)	3.9 (0.0)	42.6	1263 (53.0)	10%	311	3.862

Det = Deterministic run.

Stoch = Stochastic run.

Y = Yield.

f = Average effort.

CPUE = Catch Per Unit Effort in tons per boat day.

B = Total biomass.

SB = Spawner biomass.

CRIT = Optimum spawner biomass equal to the lowest observed spawner biomass.

Table 6.18. Summary of the offshore Pacific hake 1988-90 potential coastwide yields.

Management policy	Year	Yield (thousand t)	Effort (thousand d)	Average biomass (thousand t)	Spawner biomass (thousand t)	Percent exploitation
Observed	1986	209	2.96	1770	1069	12%
Expected	1987	285	4.36	1749	986	16%
Constant effort Algorithm	1988	327	3.86	1479	878	22%
	1989	228	3.86	1462	803	16%
	1990	188	3.86	1,300	726	14%
	1991	-	-	-	717	-
Mean	88-90	248 (743)				
Variable effort Algorithm	1988	587	8.03	1333	878	44%
	1989	255	6.07	1218	664	21%
	1990	182	5.39	1078	589	17%
	1991	-	-	-	596	-
Mean	88-90	341 (1024)				
Constant effort	1988	490	6.32	1389	878	35%
	1989	294	6.32	1282	716	23%
	1990	224	6.32	1096	614	20%
	1991	-	-	-	596	-
Mean	88-90	336 (1008)				
Constant catch	1988	325	3.84	1479	878	22%
	1989	325	5.82	1412	803	23%
	1990	325	8.30	1143	675	28%
	1991	-	-	-	596	-
Mean	88-90	325 (975)				

( ) = Total catch 1988-1990.

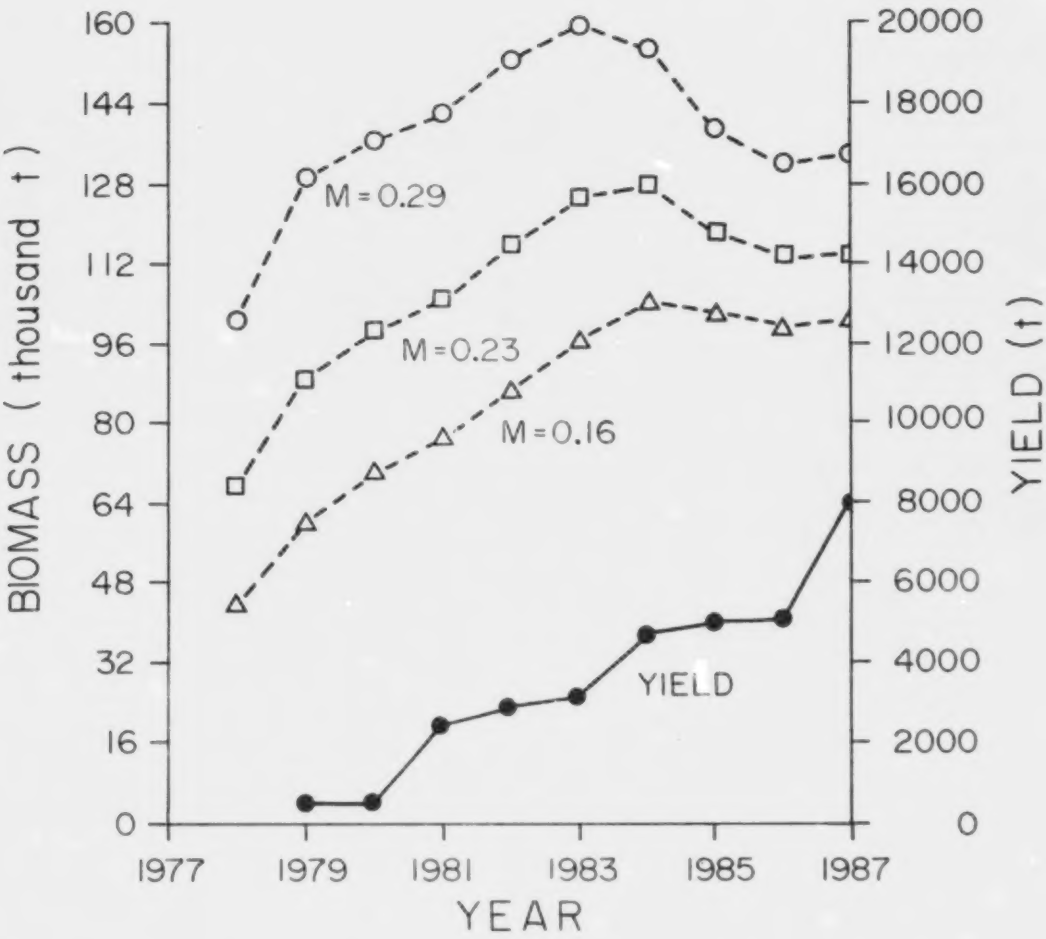

Fig. 6.1. Trends in biomass and yield from 1979 to 1987 for Pacific hake in the Strait of Georgia at varying levels of natural mortality (M).

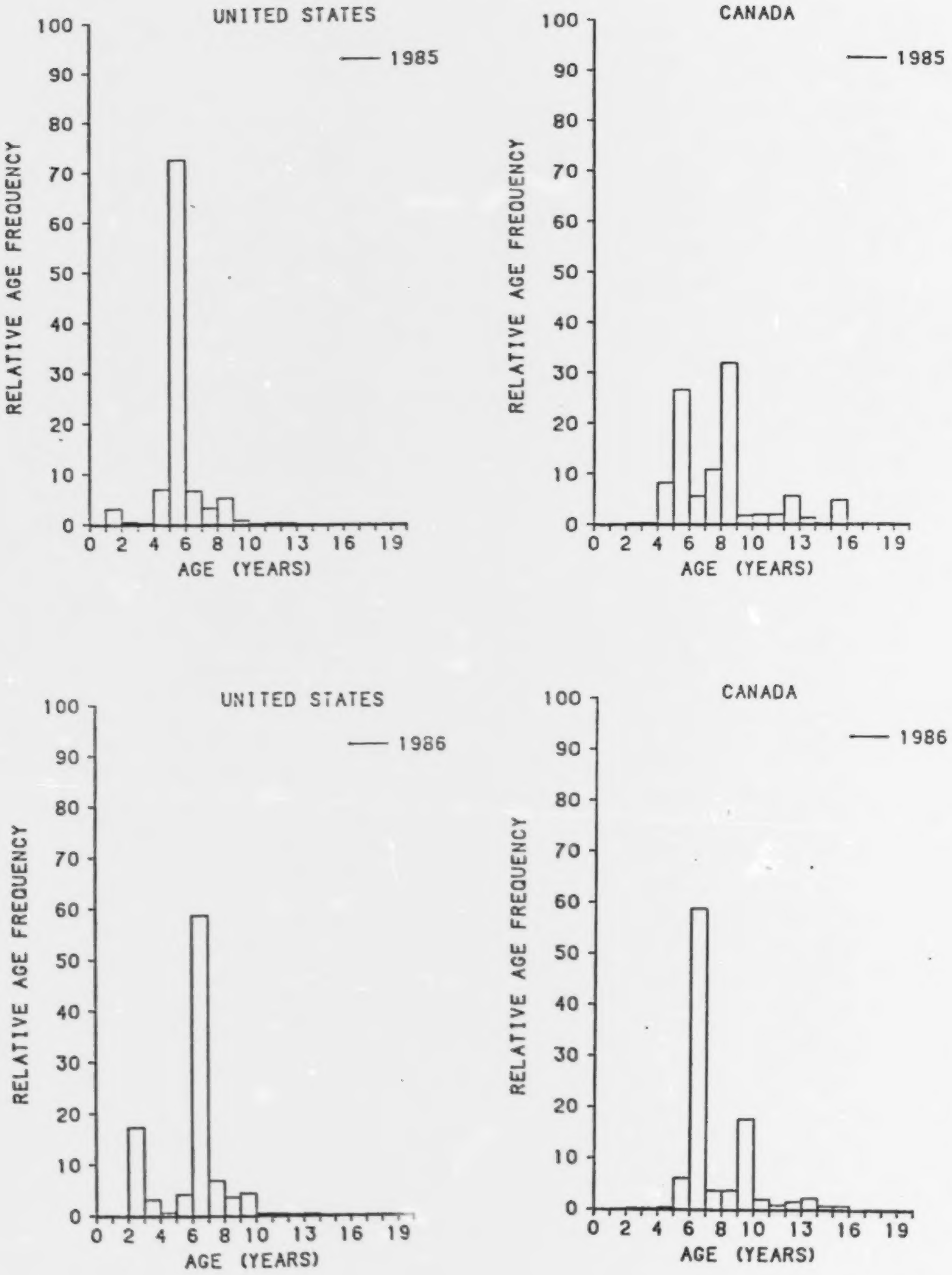

Fig. 6.2. Relative age frequency of Pacific hake catches in U.S. and Canadian waters, 1985-86.

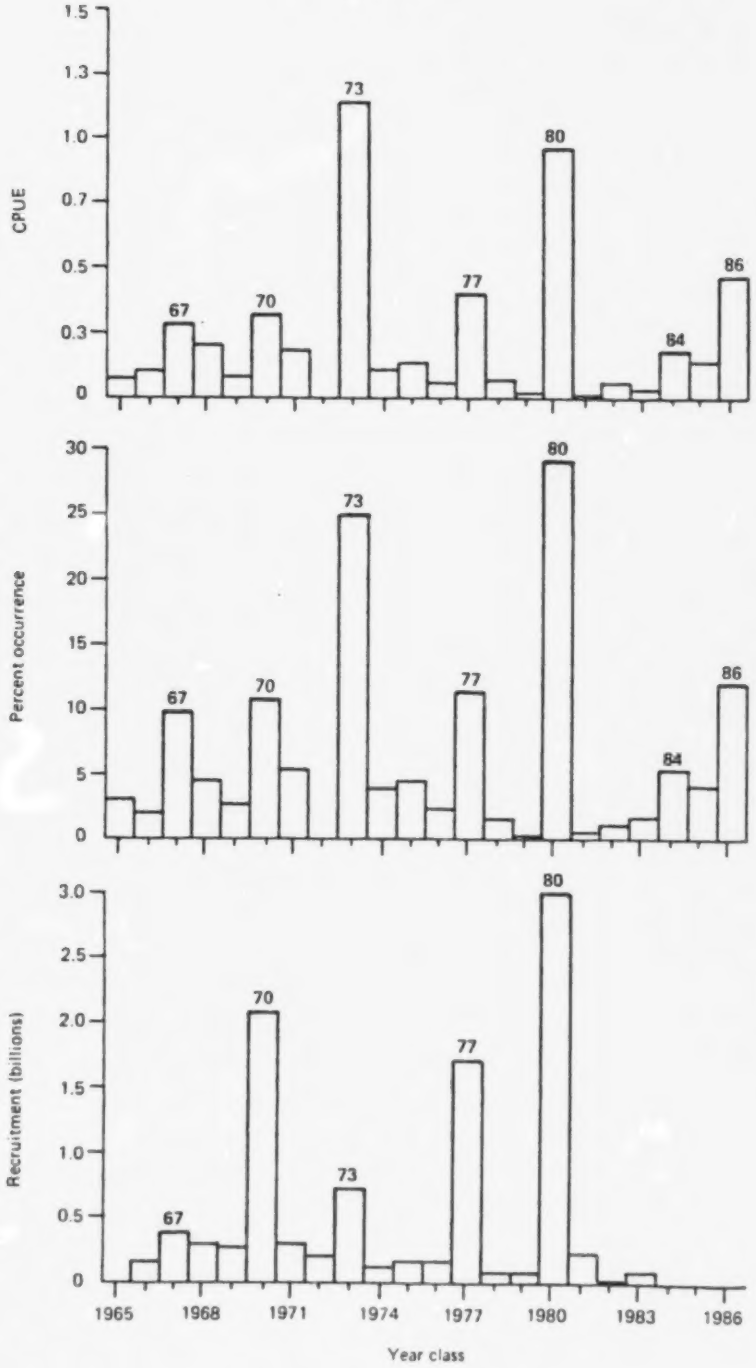

Fig. 6.3. Indices of Pacific hake year-class strength from age-0 surveys and the adult fishery. (a) CPUE of 0+ hake; (b) Percent frequency of occurrence in trawl hauls. (c) Numbers at age 3 from cohort analysis.

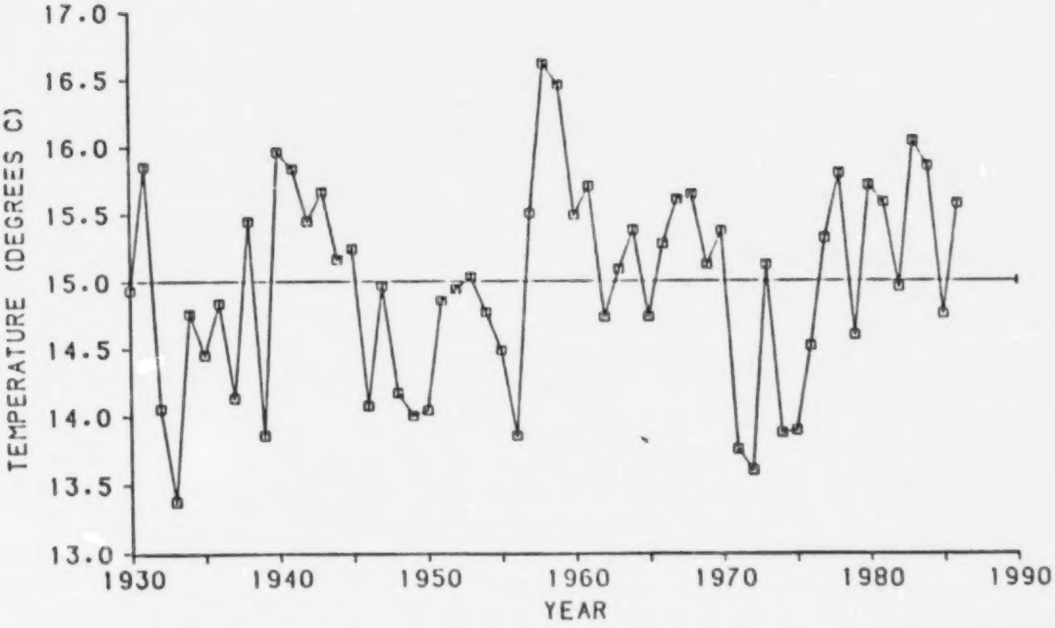

Fig. 6.4. The 1931 to 1986 mean January through March sea surface temperature (°C) in Los Angeles Bight.

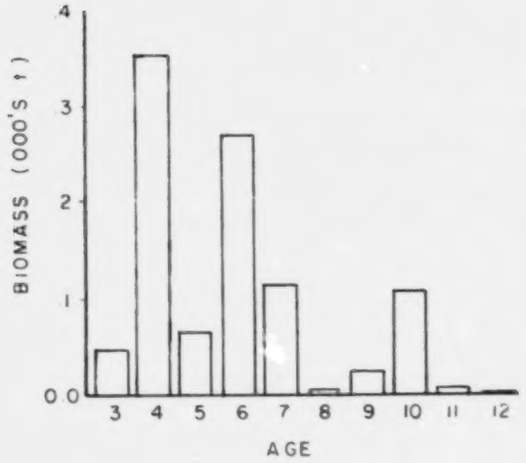

Fig. 6.5. Pacific hake biomass at age in 1990 as projected by forward simulation using constant catch of 325 thousand t (coastwide) and numbers at age in 1986 from cohort analysis.

7.0 DOGFISH

by M. W. Saunders

7.1. Coastwide (not including Strait of Georgia)

7.1.1. Introduction

The offshore stock referred to in this assessment ranges from Alaska to California and does not include the Strait of Georgia-Puget Sound stock(s). The 1988 assessment remains unchanged from the previous assessment (Saunders 1987).

7.1.2. Landing statistics

The bulk of offshore landings of dogfish in 1986 continued to come from the trawl fishery (69.7%) in Major Area 3C (Table 7.1). The fishery is primarily (91.1%) during the first and second quarters (Table 7.2) when the large fish (> 80 cm) that processors demand are available to the fleet. Total landings have increased to 2133 t in 1986 from 1959 t in 1985 (Table 7.1).

7.1.3.

Condition of stock

The model of Wood et al. (1979) has been updated with catches to 1985 (Table 7.1, 7.3). The predicted pulse in abundance set in motion by the 1940s liver fishery is levelling out from the downward trend in abundance (Fig. 7.1). At current harvest levels of less than 2500 t, the marketable biomass of dogfish is predicted to continue increasing over the next two decades. The estimated biomass coastwide at the present time is approximately 280,000 t. Assuming that one-half to two-thirds of the stock resides off the coast of Canada, the biomass of fish in the Canadian zone is between 150,000-200,000 t.

7.1.4. Yield options

Possible options include sustained yield, pulse fishing and a variable catch no-nuisance strategy.

A sustained yield fishery will also produce oscillations in abundance but they will decrease in size with time. Hence this strategy provides a steady supply while maintaining a stock size lower than present levels. For removals from the offshore stock, including Alaska, British Columbia, Washington, Oregon, and California waters, up to 15,000 t may be considered low risk sustainable and from 15,000 to 25,000 t high risk sustainable. This range is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations.

Industry has expressed concern over the high abundance of dogfish, which is viewed as a nuisance, and has asked if it is possible to maintain the population at below nuisance levels while continuing to support a directed domestic fishery.

One of the control options proposed is periodic or pulse fishing which is the removal of large quantities of fish at a specific time interval. Figure 7.1 (Saunders 1986, p. 48) illustrates the effect over time of removing a substantial catch in a single year. The biomass of marketable stock is capable of rebuilding to present levels within 3-4 years of removing 30,000 t and within 10 years of removing an unattainable figure of 210,000 t. The large removal, as discussed in Saunders (1985), accentuates and perpetuates the pulse in abundance introduced by the 1940s liver fishery. The extreme variation in abundance resulting from a pulse fishery is further illustrated by Figure 7.2 (Saunders 1986, p. 49), a forward simulation of marketable biomass with catches of 60,000 t taken every fifth year. While 60,000 t keeps the population below the present level for 10 years, over the ensuing 25 years the stock fluctuates to well above present levels and to well below a level where commercial fishing is likely to be viable. The point when fishing is assumed to be non-viable is at the level of the predicted biomass in 1950, at the end of the liver fishery when as a result of heavy fishing pressure the abundance decreased to a level where fishing success was poor.

An alternative approach entitled variable catch/no nuisance option, is to fish intensively for several years until the stock is below nuisance levels and then regulate catch to remove more fish in years when recruitment is high from the liver fishery pulse and vice versa when recruitment is decreasing. Figure 7.3 (Saunders 1986, p. 50) shows the effect of such a strategy in marketable biomass over time. Initial catches of 30,000 t for the first four years lower the stock rapidly and catches ranging from 8,000 to 25,000 t per year maintain a relatively stable stock size.

At current catch rates the trawl effort required to catch the tonnages involved is equivalent to the effort expended in a year by the entire groundfish trawl fleet on all species. One possibility is the establishment of a joint venture fishery to remove the difference of the yearly catch that domestic markets cannot utilize.

All options refer to coastwide (including U.S.) removals and no provision has been made for adjusting Canadian catches in the event of increased U.S. landings.

Yield option 1:	Sustained yield - low risk - 15,000 t
Yield option 2:	Sustained yield - high risk - 25,000 t
Yield option 3:	Pulse fishing
Yield option 4:	Variable catch/no nuisance

7.2. Strait of Georgia - Puget Sound

7.2.1. Introduction

This assessment treats the Strait of Georgia and Puget Sound as a single stock. The 1988 assessment remains unchanged from the previous assessment (Saunders 1987).

7.2.2. Landing statistics

Longline landings were down to 87 t in 1986 from 439 t landed in 1985, similarly trawl landings decreased from 432 t in 1985 to 393 t in 1986 (Table 7.2).

7.2.3. Condition of stock

The model of Wood et al. (1979) has been updated to include 1986 catches. The model predicts that the marketable biomass is increasing (Fig. 7.3) and that at current harvest levels (approx. 3000 t) abundance should continue to increase over the next few years (Fig. 7.2). Current biomass levels are in the order of 60,000 t.

Trends in relative abundance as indicated by LPUE continue to differ between longline and trawl data (Table 7.4). The trawl LPUE decreased in 1986 while longline LPUE increased. It is questionable whether these time series accurately reflect actual changes in abundance considering the low level of trip log coverage, the difficulty in estimating the actual numbers of hooks deployed (effort) and the schooling nature of this species.

7.2.4 Yield options

Dogfish may be harvested on a sustained or periodic fishery basis. The reader is referred to 7.1.4 for a discussion of the implications of pulse fishing and variable catch/no nuisance strategies.

Over the long-term, removals from the Strait of Georgia-Puget Sound stock that are in the range of 4000 t to 6000 t may be considered low risk sustainable, while removals in excess of 6000 t are considered high risk sustainable. Assuming an even split in biomass between the Strait of Georgia and Puget Sound, 2000 t is considered low risk and 3000 t is considered high risk for the Strait of Georgia.

Again, this range is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations.

Yield option 1: Sustained yield - low risk - 2000 t
Yield option 2: Sustained yield - high risk - 3000 t
Yield option 3: Pulse fishing
Yield option 4: Variable catch/no nuisance

The removals in yield option 2 and 3 refer to the Strait of Georgia only.

The trends in inshore abundance presented can be viewed only qualitatively until questions regarding the degree of mixing between Puget Sound and Strait of Georgia stocks and the impact of sports fisheries have been answered and until a reliable estimate of absolute abundance is obtained for accurate calibration of model projections.

Table 7.1. Dogfish longline and trawl landings[a] (t) offshore, by Major Area and by gear for 1979-1986.

	3C			3D			5A			5B			5C			5D			5E			Total		
	LL[b]	Tr[c]	Tot.	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot.
1979	4	279	283	1	15	16	5	10	15	-	5	5	1	11	12	26	70	96	-	-	-	33	390	423
1980	7	1732	1739	17	116	133	5	117	122	-	39	39	13	59	72	91	242	333	-	1	1	133	2306	2439
1981	10	285	295	-	17	17	-	25	25	-	-	-	-	9	9	10	32	42	-	-	-	20	368	388
1982	-	947	447	3	23	26	11	14	25	-	45	45	3	-	3	-	272	272	-	-	-	17	1301	1318
1983	77	451	528	-	54	54	16	-	16	-	9	9	-	3	3	-	17	17	-	-	-	93	534	627
1984	-	455	455	-	3	3	54	45	99	-	9	9	-	15	15	-	73	73	-	-	-	54	600	654
1985	-	1365	1365	60	74	134	360	52	412	38	2	40	-	-	-	4	4	8	-	-	-	462	1497	1959
1986	73	1770	1843	26	65	91	73	105	178	0	0	0	0	1	1	11	9	20				183	1950	2133

[a] Interview and sales slip data from Smith 1980, 1981, Leaman 1982, 1983.

[b] LL = longline.

[c] Tr = trawl.

Table 7.2. Dogfish landings[a] (t) for Major Areas 4B and 3C, by gear and quarter for 1979 to 1986.

	Area 4B											Area 3C				
	Longline					Trawl						Trawl				
	Quarter					Quarter					Grand total	Quarter				
	I	II	III	IV	Total	I	II	III	IV	Total		I	II	III	IV	Total
1979	747	206	419	2081	3453	9	7	106	669	881	4334	2	200	49	28	279
1980	806	482	23	229	1540	288	34	-	242	564	2104	512	1111	109	-	1732
1981	5	2	-	486	493	88	-	-	182	270	763	37	208	17	24	286
1982	302	67	6	464	839	100	28	120	171	419	1258	209	612	82	44	947
1983	273	128	55	336	792	81	111	70	173	435	1227	180	147	50	73	450
1984	353	260	347	635	1595	26	80	112	78	296	1891	239	127	67	22	455
1985	278	112	5	44	439	166	180	9	77	432	871	450	788	42	85	1365
1986	70	17	0	0	87	114	116	16	147	393	480	729	883	13	146	1770

[a] Includes sales slip information.

Table 7.3. Dogfish landings[a] (t) by gear from Washington State.

	Trawl	Longline	Other	Total
1983				
Inshore[b]	856	435	-	1271
Offshore[c]	21	5	-	26
1984				
Inshore	753	504	188	1445
Offshore	239	79	-	318
1985				
Inshore	469	363	139	971
Offshore	172	101	1	274
1986				
Inshore	304	325	117	746
Offshore	83	29	1	113

[a] From Technical Sub-committee, Washington State Status Reports, unpublished text.

[b] Major Area 4A.

[c] All Major Areas excluding 4A.

Table 7.4. Dogfish LPUE[a] in the Strait of Georgia[b] by year by gear.

	LPUE	
Year	Longline[c]	Trawl[d]
1979	.613	.409
1980	.651	.276
1981	.747	.317
1982	.671	.446
1983	.837	.542
1984	1.050	1.434
1985	.299	3.388
1986	.462	.976

[a] Excluding dumped and discarded fish, 25% qualification level.

[b] Including Minor Area 13, 14, 15, 16, 17, 18, 28, 29.

[c] t/1000 hooks.

[d] t/hr

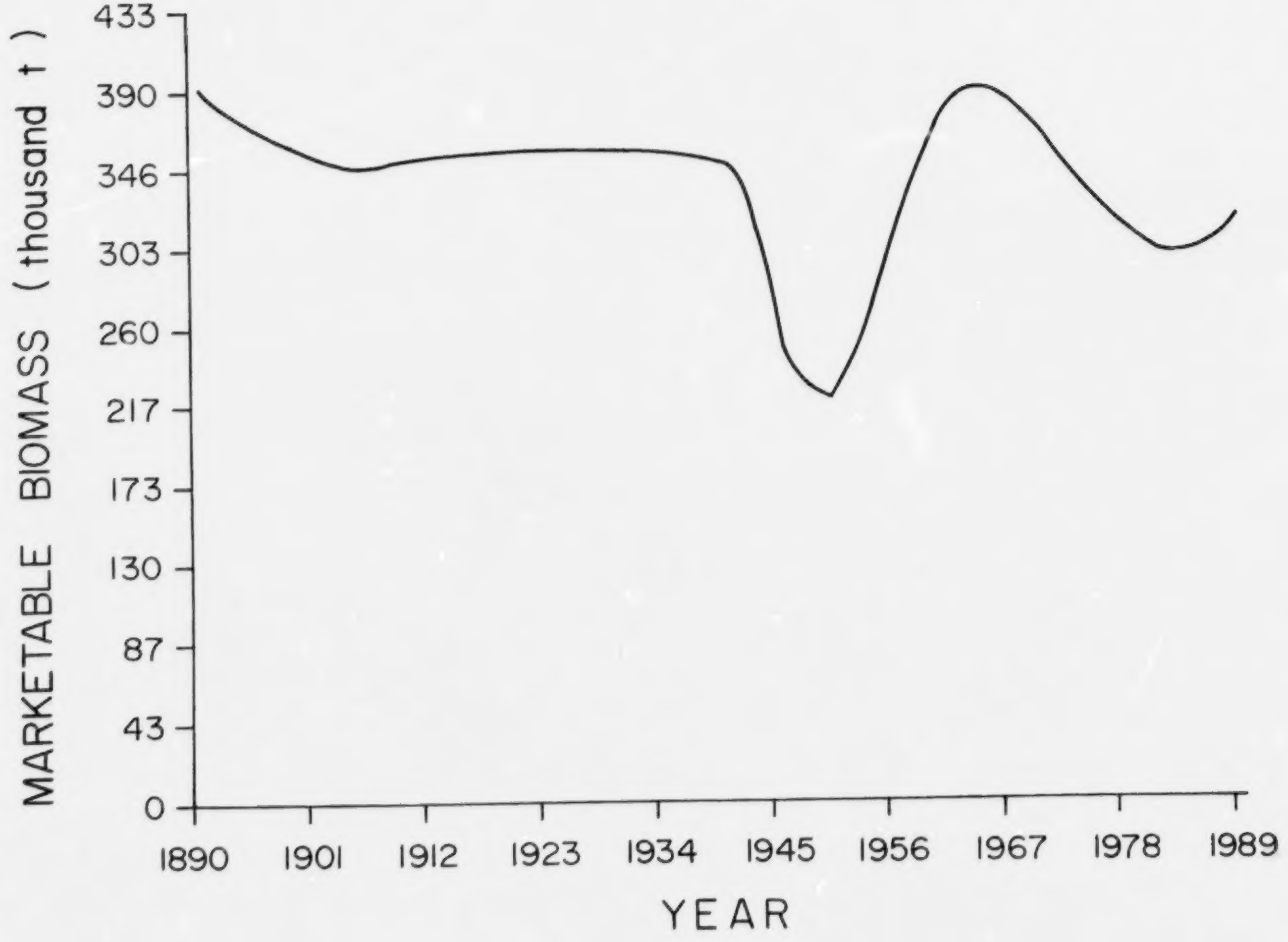

Fig. 7.1. Trends in marketable biomass of spiny dogfish, offshore, from 1890-1989 assuming a starting stock size of 390 thousand t and catches of 2500 t from 1987-89.

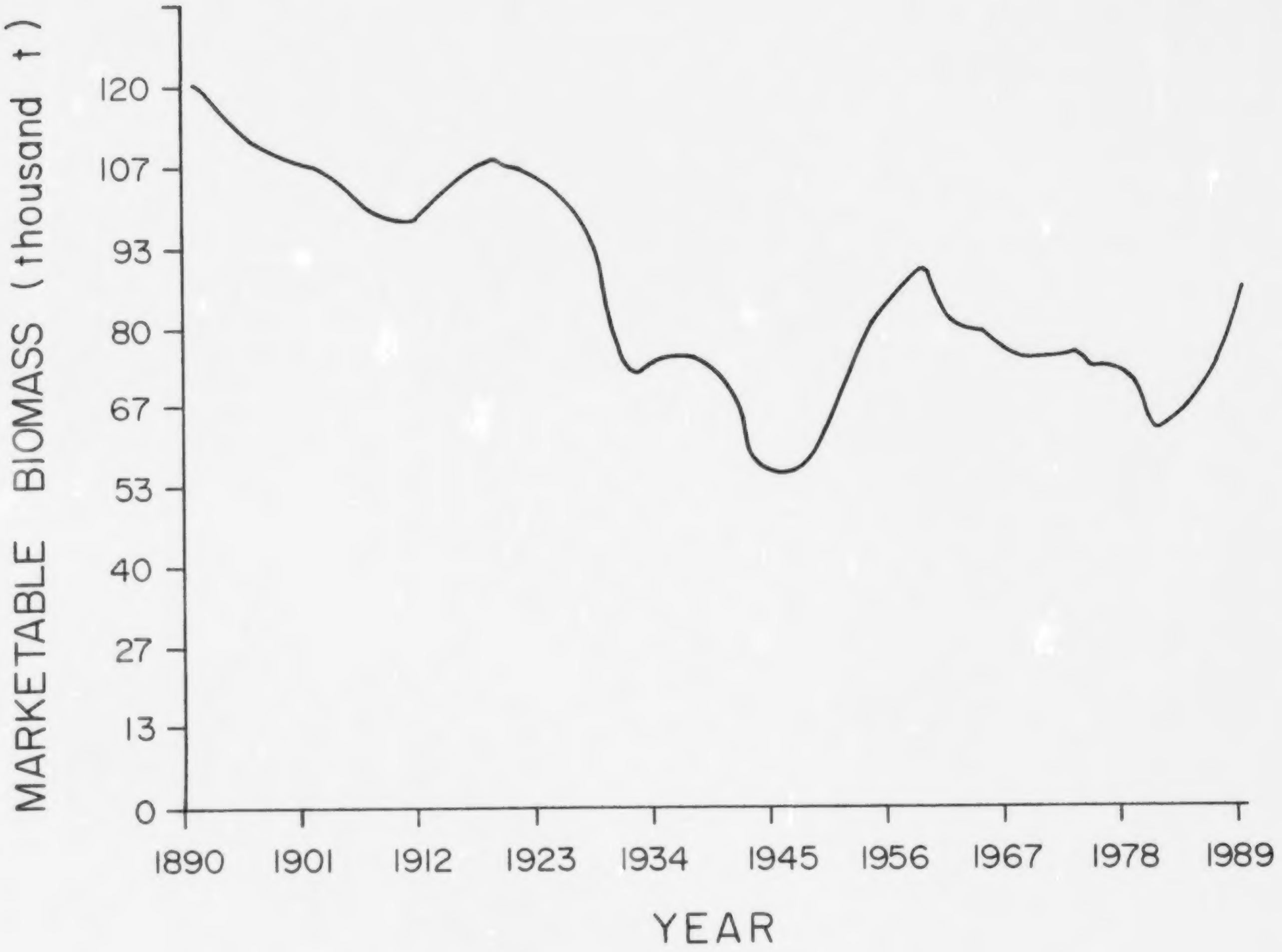

Fig. 7.2. Trends in marketable biomass of spiny dogfish in the Strait of Georgia-Puget Sound from 1890-1989 assuming a starting stock size of 120 thousand t and catches of 2000 t from 1987-1989.

8.0 WALLEYE POLLOCK

by W. Shaw

8.1. Coastwide

Yield options are not proposed on a coastwide basis.

8.2. Strait of Georgia

8.2.1. Introduction

Walleye pollock are an abundant resident fish cohabiting with Pacific hake in the Strait of Georgia. The fishery has been decreasing over the past years as a result of poor market conditions. All of the pollock catch is processed into frozen fillets which are used as a substitute for Pacific cod fillets.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.2.2. Landing statistics

During 1986, a total of 469 t was landed, a decrease of 62.7% from the 1985 landings (Table 8.1). The landings were predominantly from trawlers using midwater gear. In 1986 the fishery was concentrated in Minor Area 29 with first quarter landing of 162 t; and in Minor Area 16 in the fourth quarter of 293 t. This is in contrast to 1985 when the first quarter landings were primarily from Minor Area 17 and the fourth quarter landings were primarily from Minor Area 16 with lesser amounts from Minor Area 15.

8.2.3. Condition of stock

The size composition data indicate little change from the previous years. Modal size continues to range from 40-43 cm. Presumably the stock has remained in stable condition.

There have been no new analyses conducted. The 1988 assessment is based on estimates of maximum sustainable yield (MSY) using Gulland's (1970) relationship of $MSY = a(M)\ (B_0)$. The following parameter estimates used in the equation were: natural mortality (M) of 0.5-0.7; value of (a) of 0.3-0.5; and a biomass (B_0) estimate of 15,800-29,400 t (Shaw et al. 1985).

8.2.4. Yield options

The conservative level is based on the lower level of unexploited biomass B_0 (15,800 t), a natural mortality of $M=0.5$ and a constant (a) value of 0.3. The high risk level is based on a midpoint of the biomass estimate $B_0=22,600$ t, a midpoint in the natural mortality estimate $M=0.6$ and a constant value of $a=0.4$, which Gulland (1983) indicated as a realistic value for gadid-like species.

Yield options for 1988 may be chosen from:

Yield option 1: Conservative level of 2500 t.
Yield option 2: High risk level of 5400 t.

8.3. West Coast Vancouver Island

8.3.1. Introduction

Walleye pollock have remained a small incidental catch in the joint-venture Pacific hake fishery off the west coast of Vancouver Island (Major Area 3C). Small quantities of pollock are caught incidentally by the domestic fleet while targetting on other groundfish species in Major Areas 3C and 3D.

8.3.2. Landing statistics

The landings by the National fleet in 1986 remain small totalling 97 t, an increase of 21.2% from last year (Table 8.2). The domestic fleet landed a total of only 3 t (Table 8.3). The small incidental catch of pollock is largely due to the fleet avoiding large catches of pollock in the Pacific hake catch. Also the accuracy of reporting is suspect as no observers were aboard the foreign vessels during the Pacific hake fishery in 1986. All of the domestic catch came from Major Area 3C.

8.3.3. Condition of stock

Biological information collected during the fishery is limited. The size composition remains unchanged from the previous years. Pollock ranged in size from 35 to 54 cm with a mode at 37 cm. Very few fish were larger than 40 cm.

There has been no new analysis for the 1988 assessment.

8.3.4. Yield options

The yield option remains unchanged from the previous assessment (Shaw et al. 1985).

Yield option 1: Unrestricted yield

8.4. Queen Charlotte Sound

Yield options are not proposed for this region.

8.5. Hecate Strait

8.5.1. Introduction

The walleye pollock fishery in northern Hecate Strait and Dixon Entrance (Major Area 7 and 8) occurs mainly in the winter months, from November to December, when fish are processed into fillets and act as a substitute for Pacific cod. There is no demand for pollock roe and the markets have not improved since the late 1970s.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.5.2. Landing statistics

Pollock landings in 1986 decreased to 95 t from the high landings in 1985 of 1176 t (Table 8.4). There were no landings from Major Area 7. The majority of the landings came from trawlers using midwater gear and were confined mainly to the first quarter. The low level of catch in 1986 is attributed to the low demand for the fillets, as there was a surplus of fillets in cold storage.

8.5.3. Condition of stock

Size composition of the 1986 landings indicate that larger fish were landed than last year. The modal sizes increased approximately 3 cm to 55-57 cm.

No new analysis was conducted this year.

8.5.4. Yield options

The yield option for 1988 remains unchanged from the previous assessment (Shaw et al. 1985). The catch is currently limited due to weak markets.

Yield option 1: Unrestricted yield.

8.5. West Coast of Queen Charlotte Islands

Yield options are not proposed for this region.

Table 8.1. Walleye pollock landings by gear type and by quarter from the Strait of Georgia (Major Area 4B), 1976-1986.

	Major Area 4B		
Year	Quarter 1	Quarter 4	Total
1976			
MWT[a]	-	-	0
BT[b]	3	23	26
Total	3	23	26
1977			
MWT	-	-	0
BT	24	26	51
Total	24	26	51
1978			
MWT	177	-	177
BT	142	41	203
Total	319	41	380
1979			
MWT	1033	3	1036
BT	283	20	304
Total	1316	23	1340
1980			
MWT	841	-	841
BT	189	23	215
Total	1030	23	1056
1981			
MWT	455	-	465
BT	99	5	105
Total	554	5	570
1982			
MWT	81	-	81
BT	8	7	19
Total	89	7	100
1983			
MWT	19	-	19
BT	3	2	6
Total	22	2	25
1984			
MWT	8	90	155
BT	-	2	2
Total	8	92	157
1985			
MWT	401	319	724
BT	5	19	24
Total	406	338	748
1986			
MWT	162	294	457
BT	10	2	12
Total			469

[a] MWT = Midwater trawl.

[b] BT = Bottom trawl.

Table 8.2. Incidental catches of walleye pollock by foreign fleets participating in the offshore hake fishery off west coast Vancouver Island (Major Area 3C), 1980-1986. (Catch statistics from Offshore Division, Vancouver.)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1980	Poland	487	236	
	USSR	63	584	
	Japan	142	0	
	Greece	-	175	
	Total	692	995	1687
1981	Poland	131	205	
	USSR	26	299	
	Japan	9	0	
	Greece	-	285	
	Total	166	789	955
1982	Poland	468	222	
	USSR	0	149	
	Japan	38	-	
	Total	506	371	877
1983	Poland	13	6	
	USSR	-	-	
	Total	13	6	19
1984	Poland	1	66	
	USSR	-	41	
	Total	1	107	108
1985	Poland	2	78	
	Total	2	78	80
1986	Poland	14	19	
	USSR	1	63	
	Total	15	82	97

[a] "National" landings include landings from the supplementary fishery.

Table 8.3. Total landings (t) of walleye pollock by the domestic fleet by major statistical area, 1954-86.

	Landings (t)									
Year	4B	3B	3C[a]	3D	5A	5B	5C	5D	5E	Total
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	426
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	0.3	0	0	14	0	145
1959	260	0	8	0	0.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	0.1	0	1	0	0.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	29
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	0.4	0	1	0.1	0.4	82	0	121
1967	33	1	0	0	1	0	7	48	0	90
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	125
1970	45	0	0	0	0	0	0	8	0	52
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	0.3	0	172	0	0	1	0	244
1973	9	0	0.1	0	62	9	0.4	13	0	93
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	104
1976	26	0	5	2	69	400	193	627	0.2	1,322
1977	50	0	10	0	61	175	16	567	12	891
1978	380	0	6	0.4	106	187	11	1,700	21	2,411
1979	1,341	0	31	0.3	72	71	238	1,566	67	3,385
1980	1,056	0	3	3	12	23	83	1,103	18	2,303
1981	570	0	8	1	2	10	79	563	22	1,255
1982	100	0	10	0	1	6	3	808	1	974
1983	25	0	3	1	11	10	6	986	28	1,070
1984	157	0	5	0	11	7	2	625	< 0.1	807
1985	748	0	4	0	0	1	0	1176	2	1,931
1986	469	0	3	0	0	0	0	95	0	567

[a] Excludes incidental landings by the foreign fleet participating in the offshore Pacific hake fishery during 1980 to 1985.

Table 8.4. Walleye pollock landings by gear type and by quarter from Major Areas 5C and 5D, 1976-1986.

	Major Area 5C				Major Area 5D			
Year	Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarters2,3	Quarter4	Total
1976								
MWT[a]	-	25	102	127	-	208	56	264
BT[b]	<1	19	47	66	5	141	214	360
Total	<1	44	149	193	6	349	270	625
1977								
MWT	-	-	-	0	<1	<1	-	<1
BT	1	14	1	16	34	509	24	567
Total	1	14	1	16	34	509	24	567
1978								
MWT	-	1	-	1	425	299	71	795
BT	1	7	2	10	107	657	141	905
Total	1	8	2	11	532	956	212	1700
1979								
MWT	-	-	-	0	593	52	11	656
BT	1	103	134	238	119	521	270	910
Total	1	103	134	238	712	573	281	1,566
1980								
MWT	-	<1	-	<1	201	261	9	471
BT	1	73	9	83	116	482	34	632
Total	1	73	9	83	317	743	43	1,103
1981								
MWT	-	-	-	0	61	-	79	140
BT	27	21	31	79	71	248	104	424
Total	27	21	31	79	132	248	183	563
1982								
MWT	-	-	-	0	2	-	607	609
BT	<1	3	<1	3	4	98	97	199
Total	<1	3	<1	3	6	98	704	808
1983								
MWT	-	-	-	0	-	34	784	818
BT	-	6	-	6	43	46	79	168
Total	0	6	0	6	43	80	863	986
1984								
MWT	-	-	-	0	301	-	266	567
BT	-	2	-	2	13	40	5	58
Total	0	2	0	2	314	40	271	625
1985								
MWT	-	-	-	0	369	0	754	1123
BT	-	-	-	0	10	42	1	53
Total	0	0	0	0	379	42	755	1176
1986								
MWT	-	-	-	0	66	0	2	68
BT	-	-	-	0	8	18	1	27
Total	0	0	0	0	74	18	3	95

[a] MWT = Midwater trawl.
[b] BT = Bottom trawl.

9.0 SLOPE ROCKFISHES (*Sebastes alutus*, *S. reedi*, *S. aleutianus*, and *S. proriger*)

by B. M. Leaman

9.0.1 Introduction

The 1987 assessments for slope rockfishes contain several departures from previous practices. Firstly, no coast-wide options are presented because management has indicated that stock-specific management is the primary goal, due to the higher total yield available with that approach. Coast-wide management results in a number of significant compromises that restrict the ability of managers to allocate the sum of the individual stock yields. It also entrains a number of specific assumptions about the basis for total rockfish production, which do not appear justified.

Secondly, sustainable yield options are presented as a range of values (Table 9.1). This range varies in width depending on our relative level of confidence in the data upon which the assessments are based. The lower value in the range represents a sustainable yield level with a low risk of error, while the upper value represents a relatively high risk of error. In other words, there is not a uniform probability of error throughout this range; assigning yields at the upper limit definitely carries greater probability of error. In addition, the conservative and non-sustainable options are presented as limits (e.g. greater than or less than xxx t), rather than as specific values. While we have in past presented single values for yield options, there is imprecision in both observations and techniques and a range of values more accurately reflects the precision of our understanding. The conceptual basis for these figures remains as outlined in previous documents (Leaman 1985).

Thirdly, the exploitation of rockfish stocks throughout the world has been a consistent history of rapid depletion and long periods of attempted rehabilitation (Leaman 1987a). While it is clear that rockfish stocks cannot maintain high levels of fishing mortality, it is also clear that levels of biomass supporting long-term maximum yields will probably be lower than virgin biomass. For example, Archibald et al. (1983) estimated this level of biomass to be approximately 47% of unfished levels. However, the optimum trajectory of approach to this lowered level is not well determined, i.e. should the stock be depleted rapidly or slowly to this level? Answering this important question is one of the most difficult tasks facing population biologists, since there is no record of successful long-term management of any rockfish population. There is also no guarantee that the patterns of recruitment generated by stocks at unfished levels will be maintained at these lower levels. We have recently argued that population and fishery persistence should be grounded in the conservation of evolved characteristics of rockfishes, including the expected lifetime reproductive output of recruiting fish (Leaman 1987a). Past stock-recruitment patterns arose during periods of extended residence of adults in the spawning stock, thus allowing these populations to endure long periods of poor recruitment. Rapid depletion to the level supporting long-term yields may jeopardize this population stability. The resolution of this problem may take considerable time and require prudent experimentation.

Lastly, unlike previous years, no Recommendations are presented in the assessments. This practice arises because our assessments represent only the biological view of stock yield. Management policies stem from the integration of these results with those from social and economic assessments, as well as with views expressed by the Groundfish Advisory Committee. Recommendations in this document would therefore be inappropriate, since they might correctly be perceived as a restriction of management prerogatives.

9.3.1 Southwest Vancouver Island Pacific ocean perch (Sebastes alutus)

9.3.1.1 Introduction

No new Canadian analytic studies have been conducted since the previous assessment. More detailed information from the 1985 biomass surveys of the U.S. and Canada is available, as well as an updated assessment of the INPFC Vancouver area stock by U.S. biologists. In 1987 the quota for the 3C stock was returned to the recommended sustainable level (100t) after a 4-y overharvesting experiment (Leaman 1985). It is notable that landings from the stock did not achieve the quotas in any of the years of this experimental program, despite a large increase in effort during 1985.

9.3.1.2 Landing statistics

Nominal statistics of the fishery are variable but have generally declined and showed an inverse relation with effort, since the fishery was re-opened in 1980 (Table 9.2). Statistics of the qualified (25%) fishery showed greater declines (Fig. 9.1), with the exception of 1986 when the increase in LPUE was accompanied by a 73% decrease in effort. Statistics of the 1987 fishery are less meaningful due to the restriction to an incidental fishery only. Nonetheless, there has been as much qualified effort in 1987 as in 1986 and qualified LPUE has remained at the 1986 level.

9.3.1.3 Condition of the stock

The 3C S. alutus stock remains in poor condition and may have further deteriorated since the last assessment. Qualified catch rates have declined over 50% since the 1979 survey (Lapi and Richards 1981). The 1985 U.S. and Canadian biomass surveys showed declines of 63% and 56% in the estimated size of the S. alutus stock, respectively. Those areas receiving the greatest fishing effort since 1979 (Estevan, Clayoquot, Cape Flattery) showed the greatest relative declines in biomass (Leaman et al., in press). While reliable absolute estimates of rockfish biomass are difficult to obtain (Leaman and Nagtegaal 1986), the conjunction of lower relative estimates from both the Canadian and U.S. surveys, and the lowered catch rates from the commercial fishery, argue strongly that the relative decline also represents a significant absolute decline.

A new analytic assessment of the Vancouver Area S. alutus stock has recently been completed by U.S. biologists (Ito et al. 1987). That assessment concludes that the stock has declined from a level of ≈68-72,500 t prior to 1965, to a range of ≈4200-5700 t in 1986. The biomass estimate from the 1985 U.S. survey was ≈2030 t; i.e, the analytic estimate is 2-2.8 times the survey estimate. Proportionate discrepancies of this level should be expected from swept-area surveys for rockfishes. The U.S. assessment concludes that "the stocks in the Vancouver area are in poor and perhaps worsening condition" (p. 43), and that, "recruitment failure is viewed as a strong possibility at these low stock levels" (p. 37). The report considers ≈52% of the stock biomass to be in the U.S. zone and identifies the biomass producing MSY as ≈25,000 t.

Biological data from the two surveys (Leaman et al., in press; Ito et al. 1987) show no signs of substantial recruitment in recent years. Mean sizes of fish from samples in both surveys show slight increases from 1979, to be expected from growth, but no evidence of strong recruiting cohorts in the 30-36 cm range, upon which the fishery will depend in future years (Fig. 9.2). Comparison of length frequencies with those generated with known mortality rates, using the method of Stanley (1987b), indicates that S. alutus in this area have experienced total mortality rates of ≈0.50. This level is approximately 400% above the equilibrium rate of 0.10.

The 1985 Canadian survey produced an estimated range of S. alutus biomass of ≈1550-2180 t. Equilibrium yields (F=M=0.05) from this biomass would be in the range 80-110 t. It is recognized that the biomass estimate from the survey is likely to be conservative, however it is also apparent that even a doubling of the estimate would not alter the conclusion that the stock is severely depressed from optimum conditions. Optimal long-term stock size is in the range of 25,000-32,000 t, depending on the estimates of virgin stock size and the productivity relationship of the species used. For example, Ito et al. (1987) calculated maximum productivity at ≈0.33 of virgin biomass but cautioned that the productivity-stock size relationship employed is extremely uncertain. Alternatively, Archibald et al. (1983) calculated maximum productivity at ≈0.47 times virgin biomass, on the basis of a detailed biological model.

9.3.1.4 Yield options

The S. alutus stock off southwest Vancouver Island remains in poor condition. Equilibrium yield estimates range from ≈70-200 t (Table 9.1). The upper end of this range is probably not sustainable in view of the poor recruitment expected over the next 5-8 y. Rehabilitation of this stock cannot be expected within the next decade, even with very low fishing mortality. Perhaps of greatest concern is the possibility of complete recruitment failure for the stock. Unfortunately, we have little information upon which to base recruitment estimates at low stock levels. Collapse and continued depression of rockfish fisheries in other areas (Leaman 1987a) should, however, be borne in mind when developing management strategies.

9.3.2. Southwest Vancouver Island redstripe rockfish (Sebastes proriger)

9.3.2.1 Landing statistics

Historical landings of S. proriger off southwest Vancouver Island have been extremely limited (Table 9.3). However, in 1986 the adoption of coastwide slope rockfish quotas, and rapid subscription thereof, forced the domestic fleet to search for other red rockfish to satisfy strong market demands.

Although considerably smaller than S. alutus in most areas, S. proriger do attain marketable size (>30 cm) off southwest Vancouver Island and their landings underwent a dramatic increase in 1986, particularly after the existing slope rockfish quotas were filled. Nominal LPUE in 1987 has been similar to that of 1986, although qualified (25%) LPUE has increased.

9.3.2.2 Condition of the stock

No quantitative conclusions concerning the condition of this stock are possible. There are no biological samples and the fishery results are too limited to be of use. The continental slope area off Vancouver Islnd is relatively broad and provides sufficient habitat to harbour a reasonable stock of S. proriger. In other areas (Leaman and Nagtegaal 1982) this species co-habits with S. alutus, although at lower densities, and yields in the 200-1000 t range may be possible in this area. In some opposition to this conjecture is the evidence from foreign vessel observations (Leaman et al. 1978) that S. proriger was caught and retained in quantities aboard Japanese (and perhaps Soviet) trawlers fishing off the B.C. coast, although this is believed to have occurred mainly after the reduction in the S. alutus stocks (Ketchen et al. 1978). In addition, while the history of serious exploitation in this area is relatively short, the absolute level of LPUE is considerably lower than other areas (e.g. Moresby Gully) where "new" fisheries on major stocks have developed.

9.3.2.3 Yield options

The sustainable yield for S. proriger in Area 3C is estimated to range from 200-1000 t. In the absence of detailed analysis, but recognizing the biological affiliation of the species and rockfish exploitation histories, it might be prudent to maintain yield at ≤500 t for a period sufficient to evaluate its suitability (≈5y).

9.4.1 Northwest Vancouver Island Pacific ocean perch (Sebastes alutus)

9.4.1.1 Landing statistics

A major increase (179%) in directed fishing effort for S. alutus off the northwest coast of Vancouver Island occurred in 1986 (Table 9.4). This increase was coincident with the adoption of coastwide quotas and trip limits of 89 t. The net result of this management strategy was to discourage trips to more distant localities and pay a premium for rapid acquisition of trip limits. Fishing areas offering acceptable catch rates which were closest to delivery ports therefore attracted the majority of fishing effort, although the catch rates were lower than those at grounds traditionally fished during that time of year (1.0 vs 1.5-1.8 t/h). The participation of greater numbers of freezer trawlers exacerbated this situation, since the lower trip limits represented a smaller relative penalty for these vessels, compared with wet-fish trawlers. The 1987 fishing year has shown a return to the traditional distribution of fishing effort for S. alutus, and that in Area 3D has dropped from the same period in 1986. Additionally, fewer freezer trawlers have participated in the 1987 fishery.

9.4.1.2 Condition of the stock

There is little information upon which to base an assessment for this area. In spite of large landings in 1986 there were no biological samples obtained, primarily because much of the total was landed at U.S. ports. In recent years the area has supported landings of ≈250 t/y but the impact of the 1986 fishery is difficult to assess. The increase of qualified LPUE in 1987 is associated with a major reduction in directed effort (-89%) and contains little useful information. While there is little information available for *S. alutus* in this area, the continuity of distribution to Triangle Island suggests some alliance with the Queen Charlotte Sound *S. alutus* stock.

9.4.1.3 Yield options

The catch history of *S. alutus* in Area 3D suggests that the historical fishery, although it has been brief, has been able to sustain removals of ≈250 t/y. The upper limit of sustainability is unknown, however some guidance may be obtained from the progression of other rockfish fisheries (Francis 1986) wherein estimated levels of long-term sustainable production ranged from 1-5% of virgin biomass. Archibald et al. (1983) estimated maximum long-term yield as ≈2% of unexploited biomass. However, the comments concerning the trajectory of approach to optimum stock levels, made in Section 9.0.1, are pertinent here.

The intense *S. alutus* fisheries of the mid-1960s found no significant quantities of fish in Area 3D, hence the virgin biomass must have been considerably less than those of either Queen Charlotte Sound (≈80,000 t) or southwest Vancouver Island (≈68,000 t). If the biomass was in the 10,000-30,000 t range, then long-term sustainable yield might be ≈200-600 t (Table 9.1).

9.5.1 Queen Charlotte Sound/Northwest Vancouver Island redstripe rockfish (*Sebastes proriger*)

9.5.1.1 Landing statistics

Historical landings of *S. proriger* off northwest Vancouver Island and in Queen Charlotte Sound have been extremely limited, until 1986 when over 1000 t were landed (Table 9.5). The reason for this sudden increase related to the adoption of coastwide quotas and rapid subscription thereof, detailed in Section 9.4.1.1. The nominal and qualified LPUE for this fishery are relatively modest for a new fishery, although both have increased in 1987. Historical catches by foreign trawlers in this area may have been substantial (Leaman et al. 1978).

9.5.1.2 Condition of the stock

There is almost no information upon which to base the assessment of this stock, other than fishery statistics. No biological samples have been obtained, in the short period of the fishery. There is clearly uncertainty concerning the condition of this stock, however we caution that it is a *Sebastes* sp. and therefore extremely vulnerable to exploitation.

9.5.1.3 Yield options

The yield options for S. proriger in Area 3D/5A are based on published work (Francis 1986) relating initial yields from fisheries to their ultimate long-term yields. Francis estimates these latter yields seldom exceed 200-300% of initial yields. The average yield from the first six years of the fishery was ≈350t and this may be used as a lower estimate of sustainable yield (Table 9.1). The upper limit would then be estimated at ≈900 t (i.e. 250% of 350 t). Stability of quotas over the next 3-5 y may assist in the evaluation of their validity.

9.5.2 Queen Charlotte Sound/Northwest Vancouver Island yellowmouth rockfish (Sebastes reedi)

9.5.2.1 Landing statistics

The 1986 fishery recorded major landings of S. reedi from the southern portion of Area 5A and Area 3D (Table 9.6). Much of this removal was associated with the same conditions of coastwide quotas as was described in section 9.4.1.1. Catch rate has risen in 1987 although it is still below peak levels. The landings from this combined area in 1987 exceed the suggested yield option by several hundred percent; a result of several errors in the designation of quota areas during 1987.

9.5.2.2 Condition of the stock

No analytic assessments of this stock have been conducted due to a paucity of useful data. It is difficult to determine the effects of fishing, if any, in the absence of these data. The fishery during 1986 and 1987 has concentrated on aggregations of spawning females ($\bar{X}$ = 76% female) and would be expected to produce high catch rates. Comparison of size frequencies from commercial samples (mean sizes: female = 47cm, male = 45cm) with those generated by a simulation model using known mortality rates (Stanley 1987), indicates that total mortality rate experienced by the stock is in the appropriate range (Z=0.05-0.10). However, the estimation of mortality rate in this manner is of limited value for stocks where the history of fishing is short, relative to the residence and recruitment period of individual cohorts. Changes in the size frequency of the stock are driven by recruitment and are largely insensitive to short-term fishery effects.

9.5.2.3 Yield options

The stock of S. reedi in the 3D/5A area has apparently sustained removals of ≈200-250 t/y by the domestic fishery. The previous catch history by foreign vessels is less certain due to species designation problems (Leaman et al. 1978). While the upper limit of sustainable yield is unknown, at this time, it might be prudent to approach the expansion of this fishery in a staged manner. Experience in other rockfish fisheries (Gunderson 1984; Francis 1986) suggests that yields in excess of 200-300% of the initial yields (i.e. prior to the typical exponential increase in catches) from a fishery are seldom sustainable. Accordingly, the estimated upper limit for the sustainable yield option from this stock is ≈400-750 t (Table 9.1).

9.5.3 Queen Charlotte Sound (QCSd) Pacific ocean perch (*Sebastes alutus*)

9.5.3.1 Landing statistics

The 1987 fishery in QCSd was closed to directed fishing until April 1. Fishing effort has been substantial since that time (Table 9.7), although standardized (by vessel class) LPUE is the lowest on record. In part, the low LPUE for the 1987 fishery can be attributed to the imposition of trip limits (23 t) during the latter part of the year. The 1986 fishery showed LPUE values lower than both the 1983-1984 winter fisheries at the mouth of QCSd and those of the 1975-1983 period.

9.5.3.2 Condition of the stock

The QCSd *S. alutus* stocks have been analyzed more intensively than any groundfish stock on the Pacific coast. Analytic assessments have been conducted by Archibald et al. (1983), Gunderson (1978, 1981), Hightower and Grossman (1987), Kimura (1981), and Leaman (1985, 1987a,b). Analyses of trends in fishery and biological statistics were reported by Fraidenburg et al. (1978), Gunderson (1977), Gunderson et al. (1977), Ketchen (1981), Ketchen et al. (1978), and Westrheim et al. (1972). In addition, some of the analyses themselves have been analyzed (Kimura et al. 1984). All of these studies have reached the same conclusion, namely that the QCSd *S. alutus* stocks are severely reduced from their unfished abundance. This conclusion is invariant, derived with a number of independent analytical methods, and supported by the biological characteristics of the stocks. All of the analytic studies have also noted that increased yield from these stocks could be realized if they were rehabilitated to a higher biomass level. While some of these analyses are complex, it is clear that there simply are not as many fish in QCSd as there either once was or should be.

Some readers of the 1986 assessments may have interpreted reductions in the yield options for Goose Island Gully to have been based on reduction in the total reproductive output of the stock, due to the female bias in landings from the 1983-1984 winter fisheries. The 1986 assessments do not contain any correction for this sex bias, although there is concern about its impact. Decreases in the yield options resulted from an updated simulation analysis (Leaman 1985), using 1985 age composition data.

Recent analyses of this stock (Archibald et al. 1983; Leaman 1985, 1987b) reached the same conclusions as those preceding them. The sole aspect of these analyses we have not previously examined is the robustness of their conclusions to the assumptions under which they were conducted. To address these concerns we have conducted such a sensitivity analysis (Tables 9.8-9.11). This analysis examines the effect on the assessment if we change our assumptions about biological or fishery characteristics and relationships.

The sensitivity analysis employs a finite-difference calculation, using 0.1 as the perturbation (δ). The relative sensitivity of the result function, f, (biomass or yield) to variations in parameter b_i can be estimated as:

$$S_i = \frac{f(b_i+\delta b_i) - f(b_i)}{f\delta}$$

or in the case of vector inputs (e.g. partial recruitments, or number at age N(j))

$$S_i = \frac{f(e_1+\delta e_1, e_2+\delta e_2 \ldots) - f(e_1, e_2 \ldots)}{f\delta}$$

where δ is constant upon e_n (after Rivard 1982).

These sensitivity coefficients are approximations of the partial derivatives of the yield and biomass functions, with respect to the input parameters. In simple terms, they measure the relative change in estimated yield and biomass associated with given changes in the values of the input parameters. They are directly comparable in that they represent the same relative change for the various inputs.

Tables 9.8-9.11 and Figures 9.3 and 9.4 afford some understanding of the relative sensitivities of the simulations to perturbations in state and input variables, with horizons of 10, 20, 30, and 100 y. Fishing mortality is the control variable, at levels of F=0.01-0.10. The inherent biological structure and time lag of this simulation model mimic that of the natural population. Since the first age at which partial recruitment is >0.5 is 11 y, there is limited opportunity for the feedback control mechanisms of the model to assert themselves at time horizons of <30y.

At the 10y time horizon, initial values have little influence at F >0.3 and above F=0.6 no parameters have sensitivities >1.0. The initial age vector has almost no influence on yield. At horizons ≥20y the sensitivities of parameters begin to show more stable patterns, with stock-recruitment and fecundity showing more positive influence on yield and biomass. Partial recruitment and natural mortality sensitivities are negative and approximately twice the relative perturbation over 100y horizons. Variance in recruitment and perturbations of weight at age are roughly equivalent and close to 1.0. The parameters of the stock-recruit relationship (α,β), fecundity at age, and natural mortality are proportional to F in their sensitivities, while other parameters are largely independent of F.

Forward simulations of the Goose Island stock are most sensitive to estimates of fecundity at age, stock-recruitment parameters, the partial recruitment vector and natural mortality. The effects of the former are positive and the latter two negative (inverse). Yield estimates are sharply increased by increases in fecundity at age and the stock recruitment relationship, particularly at higher F values (Fig. 9.3). In contrast, increases in partial recruitment values and natural mortality decrease estimates of available yield and biomass.

The shifts in estimated yield presented in the 1987 assessment report arose from the use of 1985 age composition data as the initial N(j) vector for the simulations; previous reports had used the 1977 vector as the starting point. The effect of this change on the estimated yields is not a direct one [S(N(j)=0.05], rather it is through both initial and future recruitment associated with this changed age vector [S(recruitment)=1.0-1.3]. While there is unquestionable imprecision in short-term yield estimation with this model, there is no indication that mean values of the replicates will be biased.

In summary, the sensitivity analysis shows that only four of the input parameters (or vectors) have appreciable influence on estimated biomass or yield. Of these four, we have good confidence in three: natural mortality, partial recruitment, and fecundity at age. The parameters of the fourth, the stock recruitment relationship, are not particularly well determined only because the relationship itself is apparently weak; increases in these parameters will therefore have disproportionate influence since they act to strengthen the relationship. Initial recruitment, numbers at age, and recruitment variance have relatively little influence on estimates of long term yield and biomass.

Hightower and Grossman (1987) have recently completed an independent analysis of optimal policies of rehabilitation for overexploited resources, using a deterministic model, and included the QCSd S. alutus stock as one of their examples. While their deterministic model limits the realism of the analysis, it is noteworthy that the periods of rehabilitation they estimate for this stock (60-90 y) are even longer than those from our analyses. They noted that, "...rehabilitation will be particularly difficult for long-lived fishes such as Pacific ocean perch, because changes in stock size will be slow and may be masked by variability in recruitment..." (p. 809). They further noted that target-harvest policies of rehabilitation (the policy in place for the QCSd stock) were superior to either target-biomass or target-spawning policies, in terms of reducing variability in yields over the planning horizon.

9.5.3.3 Yield options

As with all rockfish stocks, the dynamics of the Goose Island Gully stock of S. alutus are relatively slow and rehabilitative management actions of even large measure have little impact over the short term. Previous work (Archibald et al. 1983; Leaman 1985) has shown that, with the exception of complete closure, there are relatively small differences in the periods of rehabilitation between F=0.0-0.05. While there may be uncertainty about the exact level of stock biomass in 1987, the values of F associated with long term maximum yield are relatively well determined (F=0.06). Present stock biomass is estimated to be in the range of 8000-13000 t, suggested by the simulations using the 1985 and 1977 age compositions (N(j)), respectively. Yields from these biomasses are dependent on the choice of management policy and have been outlined in previous assessments (Table 9.1). For example only, yields at F=0.06 would range, including the contribution of the Mitchell's Gully component of the stock, from ≈700-1000 t. If management considers maximum available yield to be a desirable management goal then a winter fishery, with its female bias, would reduce available yield relative to an unbiased summer fishery.

9.6.1 Moresby Gully Pacific ocean perch (*Sebastes alutus*)

9.6.1.1 Landing statistics

Catch rates for this stock (Table 9.12) do not display a healthy pattern, in relation to previous experience with rockfish stock histories. There were low catches and catch rates until 1980 when the stock first began to be exploited by the commercial fishery (this stock was discovered by the Department in 1973). After an initial learning period, the fleet began to target the stock heavily and catch rates first rose, then declined. The 1986 catch rate is probably abnormally low, due to effort diversion elsewhere during coastwide quota management. Between 1983-1987 the qualified (25%) catch rate declined by 31% (Fig. 9.5). If rockfish stocks in other areas had shown greater resilience to fishing effort this pattern might not be of concern. However, there are no indications that the levels of effort which yield such catch histories are sustainable (Francis 1986). For the Moresby stock, catch statistics suggest negative effects of fishing effort. Quantifying this effect is difficult without a time series encompassing the residency of several cohorts in the fishable stock; such data are unlikely to be available before the 1990s.

9.6.1.2 Condition of the stock

Assessment of the Moresby Gully stock of *S. alutus* continues to be hampered by the lack of a detailed history of its age composition and the relatively short history of its fishery. It is therefore difficult to detect fishery effects, if any, due to the late age at full recruitment (partial vulnerability is >0.5 only at ages ≥11y) and the 'fishing up' effect common to fisheries on this type of species (Francis 1986; Leaman 1987a). The 1987 assessment relies upon interpretation of stock status as portrayed by catch statistics and length frequency composition. Previous assessments (e.g. Leaman 1985) have also employed estimates from biomass trawl surveys. Recent results (Leaman and Nagtegaal 1986) cast doubt on the value of swept area surveys for estimation of absolute biomass of rockfish stocks, on the basis of extreme within-site variance. However, the last survey estimate (Leaman 1985) is less conservative than that of traditional surveys because catch rates only from directed fishing on schools alone, were applied to the entire area of strata. Traditional surveys use catch rates from systematic fishing at random locations, resulting in much lower average catch rates and biomass estimates. Traditional surveys will generally tend to underestimate rockfish biomass, thus the relative bias of the last Moresby survey is less.

Length frequencies of samples from research and commercial fishing in Moresby Gully were compared with length frequencies generated by a simulation model, using known mortality rates. This model (Stanley 1987) is based on the conceptual model of Fournier and Breen (1983) and Schnute and Fournier (1980). It incorporates stochastic recruitment, variation in lengths at age, and variation of mean lengths from those of a perfect growth function. The limitations of the technique are (i) that shifts in length frequencies are recruitment driven, and therefore may be insensitive to quite large mortality effects at initial stages of a fishery on species where recruitment is normally a small proportion of the standing stock, and (ii) at present the model assumes mortality effects have been experienced throughout the period of residence for stock cohorts. It can, however, serve as a general indicator of mortality effects in the shorter term.

For the Moresby stock, there are a number of specific constraints that hamper mortality rate estimation. Chief among these is the seasonal pattern of availability by size and sex within commercial fishery samples. Spring samples from this stock invariably show smaller fish than those in summer and fall fisheries (Fig. 9.6). Obviously, one could generate very high estimates of mortality with particular sample selection. Figures 9.7 and 9.8 show simulated length frequencies at the desired total mortality rate for Moresby fish compared with the aggregate samples from 1981, 1983, and 1985. The smaller mean sizes in more recent years suggest high mortality rates in relation to the target of F=M=0.05 (i.e. Z=0.10). In recent years the fishery in Moresby Gully has been concentrated in the spring of the year, hence size frequencies in commercial samples (Figs. 9.9 and 9.10) have reflected this seasonal bias. The second constraint concerning the Moresby stock of S. alutus is the prominence of the 1952 cohort (Leaman 1985). This cohort exerts a dominant influence on all stock characteristics and because it is now 35 y old, annual increments in length are almost undetectable, (Archibald et al. 1981) as are shifts in lengths associated with recruitment. The model does afford limited consideration of such dominance.

To account for the above concerns, samples for mortality rate comparisons were selected only from the same area (Cape St. James), using the same gear, and during the time of year when all size classes were available (summer-fall). Unfortunately, this precludes the use of the two most recent years' data, because the samples are all from the January-April period. Use of these two data sets would strongly bias the mortality estimate for these years (Figs. 9.9 and 9.10).

The comparison of 1981-1985 data with the Z=0.10 reference frequency (Figs. 9.7 and 9.8) is inconclusive. The 1985 data are from October and the presence of large numbers of 36-38 cm fish may indicate some contamination with 'spring' characteristics. Alternatively, a massive recruitment pulse may be involved, but no other evidence of large recruitment (e.g. reported discards, large presence of pre-recruits in age samples) has been noted. Lastly, the presence of these relatively larger numbers of smaller fish may indicate high mortality rates in recent years.

Catch rates for the S. alutus stock in Moresby Gully are cause for concern. There is no indication that the stock is increasing and the decline in LPUE, taken in the context of experience with other rockfish stock histories, suggests stock decline. Tempering this suggestion is the fact that the fleet has not fished this stock during the optimum period of availability (summer) in recent years. However, LPUE from the 1987 summer fishery has not improved over the 1985 value (1986 was considered to be abnormally low).

Mortality rate estimation from length frequencies cannot demonstrate the effects noted in the catch rates, due to the problems of seasonal availability by size class and the pattern of the fishery in recent years. Management of this stock will continue to be hampered by data limitations and the dominance of the 1952 cohort over the next 5-10 y. Effects of changes in management policy will therefore continue to be difficult to detect and evaluate. The sensitivity of rockfish stocks to high fishing effort argues that any changes in yield should be as relatively small increments applied over time intervals sufficiently long for evaluation of their effects. Recent work (Francis 1986) indicates that even large decrements in biomass (-50%) may be difficult to detect. In the interim, the negative trend in catch rates should be cause for concern.

9.6.1.3 Yield options

The foregoing assessment suggests no change in the yield options for the Moresby Gully *S. alutus* stock over those identified in the previous assessment (Leaman 1985). These options were based on a biomass estimate from a trawl survey (which will generally tend to underestimate rockfish biomass), although for that survey the bias will be less than for traditional surveys, for the reasons noted above. The yield estimates may, on that basis, be conservative. In opposition to this conjecture is the downward trend of catch rates in recent years. Previous rockfish studies (Francis 1986; Archibald et al. 1983) have shown that major shifts in catch rates such as these can indicate substantial changes in biomass. One approach to the solution of this problem may be to maintain present yields from this stock to determine if catch rate changes persist (which will indicate stock declines), or to reduce yield in an effort to reverse this trend. If changes in yield are considered, they should be as fixed steps for ≈5 y periods, which will permit sufficient opportunity for their evaluation.

A recent internal Groundfish Section review of the Moresby Gully *S. alutus* assessment has suggested that yields may be underestimated. The review noted the general unreliability of trawl survey biomass estimates and specifically noted the fact that the experimental fishery in Area 5E(N) has caught over four times the survey biomass estimate. Using a different estimate for the catching coefficient of the survey gear, the review identified a higher sustainable yield (3500 t) for the Moresby Gully stock.

The higher yield estimate identified by this review must be balanced against the fact that the Moresby Gully survey was not the traditional stratified-random design, rather it applied catch rates from fishing only on schools to the entire area of the appropriate stratum, hence would produce a relatively liberal estimate of biomass.

The present assessment for the Moresby Gully *S. alutus* stock and its internal review are conflicting. While we acknowledge the imprecision in survey results, we believe the underlying survey estimate for this stock is more liberal than previous survey estimates. Therefore, we have included 3000 t as the high-risk limit of sustainable yield.

9.6.2 Moresby Gully redstripe rockfish (*Sebastes proriger*)

9.6.2.1 Landing statistics

In concert with other fisheries for *S. proriger*, that in Moresby Gully is of relatively recent origin (Table 9.13). Landings have not yet exceeded 300 t. Qualified (25%) LPUE has been variable since the first significant landings in 1985.

9.6.2.2 Condition of the stock

There is very little information upon which to assess the S. *proriger* stock in Moresby Gully. The species exhibits strong sexual dimorphism, favouring females to the extent of gross separation of adult length frequency distributions (Fig. 9.11). Males (modal length 32 cm) are only slightly above marketable size ($\geq$30 cm), which may lead to a future sex bias in landings. A comparison of 1986 length frequencies from commercial samples with frequencies simulated by the method of Stanley (1987) suggests total mortality rates of $Z=0.20$ for males and $Z=0.10$ for females (Figs. 9.12 and 9.13). These values are approximately equal to the estimated rates of natural mortality for the species (Archibald et al. 1981), suggesting little adverse effect of the historical fisheries where this species may have been caught as a target or incidentally.

9.6.2.3 Yield options

Yield from the Moresby Gully stock of S. *proriger* cannot be determined analytically. In the absence of any adverse indications from the limited available data, we assume that the minimum historical landings can be sustained. Indeed, the large stock of S. *alutus* in this area may infer a relatively large stock of S. *proriger*, based on analysis of historical patterns of association between these species (Leaman and Nagtegaal 1987). The catch proportion ratio from that analysis (0.217) implies a yield range of 350-570 t for S. *proriger* in Moresby Gully (Table 9.1). This species might be a candidate for experimental management in one or more areas, in order to maximize information flow over the next several years.

9.6.3 Moresby Gully yellowmouth rockfish (*Sebastes reedi*)

9.6.3.1 Landing statistics

The fishery for S. *reedi* in Moresby Gully has been erratic (Table 9.14). Landings underwent a major increase in 1982 but have since declined, along with fishing effort. Both qualified (25%) and unqualified LPUE have declined since 1985, although the effort producing the former is very low in 1987. Fleet activity is generally directed at S. *alutus* in this area because LPUE for it is considerably (80-150%) higher.

9.6.3.2 Condition of the stock

There is little information with which to assess the Moresby Gully S. *reedi* stock. The recent downward trend in LPUE is associated with a similar trend in qualified effort, limiting the usefulness of the index. We will assume the mean level of harvest is sustainable and represents the minimum level of long-term yield. The association with S. *alutus* in landings is not as strong as that in Area 5E (Leaman and Nagtegaal 1987), hence catch proportion ratios are inappropriate.

9.6.3.3 Yield options

The long-term average harvest from this stock (≈160 t) is assumed to be a lower limit of sustainable yield (Table 9.1). There is little to guide the determination of an upper estimate; we will use the same criterion as in section 9.5.1.3, i.e. 200-300% of initial harvests represents a non-sustainable level (Francis 1986; Gunderson 1984). The upper limit is therefore estimated to be ≈500 t.

9.7.2 West Queen Charlotte Islands (south of 54°) Pacific ocean perch (*Sebastes alutus*)

9.7.2.1 Landing statistics

Landings of *S. alutus* from Area 5E(S) peaked in 1978 (2413 t) but have since been restricted to much lower levels (Table 9.15). This species has also been managed on the basis of a slope rockfish assemblage, with seasonal openings, since 1983. In 1987 the seasonal openings, which were designed to optimize individual species yields within the assemblage, were abandoned in favour of quarterly openings.

Present LPUE (qualified and nominal) for the fishery is well below peak levels and qualified LPUE has declined to the lowest level on record. Qualified LPUE (1.077 t/h) is only 35% of the highest value on record. Achievement of management targets has generally been poor (Leaman and Nagtegaal 1987), with overruns on quotas the rule rather than the exception.

9.7.2.2 Condition of the stock

Previous analyses of the Area 5E(S) stock (Leaman 1985) were based on biomass surveys and the application of search and depletion theory to detailed fishery statistics (Mangel and Beder 1985). The former suggested a 1979 biomass of 11,300-25,300 t, of which ≈65% was composed of *S. alutus*, *S. reedi*, and *S. aleutianus*. The latter estimated the 1977 biomass of *S. alutus* in the Rennell Sound area to be 14,200-21,900 t, although those estimates may have been high, due to some of the model assumptions. We have since examined the fishery statistics for the stock with standard depletion estimators (Leslie and Davis 1939; Ricker 1975) using Braaten's (1969) correction for interval length. This regression suggests a biomass of *S. alutus* in Area 5E(S) of ≈29,900 t in 1976. Both this estimator and more recent developments of it (e.g. Walters 1986a) have the inherent limitation of assuming constant catchability (q). When q changes, as is inevitable for aggregated species such as rockfish, the estimates of the initial population, N_0, can be seriously biased and the magnitude of the bias is dependent on the direction of the change. Braaten (1969) noted that increasing q produced stronger bias than decreasing q, and that rapid jumps in q had a more severe effect on bias than a steady increase. Additionally, the bias in N_0 was greatest immediately following changes in q and diminished with time. For the 5E(S) *S. alutus* stock, the net effect will be to overestimate the initial stock size with the use of such depletion estimators.

The stock continues to be dominated by the 1952 cohort (Fig. 9.14), now 35 y old. Over 17% of the total number of fish and a higher percentage of the biomass is accounted for by this single cohort. The dominance of this cohort, and the low recruitment rate for the area, will make detection of fishery effects on the basis of size characteristics extremely difficult. On the positive side, there are indications that the 1976 cohort may be relatively stronger than recent year recruitments, and it should be fully recruited to the fishery by 1991-1992. Calculations suggest it may be $\leq$25% of the strength of the 1952 cohort, or about the strength of the 1961-1962 cohort. The latter was almost eliminated from southern stocks by a relatively modest fishery and does not appear to have recruited in strength to Area 5E(S) (Fig. 9.14).

The size frequency of the stock in 1986 was compared to simulated frequencies calculated with known mortality rates (Stanley 1987b). This comparison (Fig. 9.15) provides a different perspective on stock status than that from the foregoing analysis and the 1984 age sample. The bimodal nature of the size frequency distribution arises from the combination of samples from two separate localities, one of which is at the northern limit of Area 5E(S) and closer to the heavily exploited Langara Spit. The smaller females (modal size 37 cm) in Fig. 9.15 are from this locality and the larger group (modal size 42 cm) are from the more southern sample. The average mortality rate for the combined samples is ≈0.25, however the estimated rates for the southern and northern samples are ≈0.15-0.20 and >0.60, respectively. Length frequencies therefore support the inference drawn from catch statistics, that historical landings from this stock may have exceeded sustainable levels.

9.7.2.3 Yield options

Some of the estimators of stock biomass for the Area 5E(S) S. alutus stock suggest that the 600 t yield presently used (Table 9.1) should be sustainable, if not actually conservative. Opposing this conclusion is the steady decline of qualified LPUE for the fishery and the length frequency distribution, arguing that this yield exceeds sustainable levels. Resolution of the paradox might best be achieved through maintenance of existing yields for an additional 2-3 y, to provide an opportunity for LPUE to reflect their suitability. Continued decline or the absence of variation will suggest that ≈600 t is an inappropriate level. Size frequency changes will also need to be closely monitored.

9.7.3 West Queen Charlotte Islands (south of 54°) yellowmouth rockfish (Sebastes reedi)

9.7.3.1 Landing statistics

Landings of S. reedi in Area 5E(S) peaked in 1977, declined in 1978 and have been regulated by quota since 1979 (Table 9.16). Nominal LPUE has declined relatively steadily since 1977 and is now <50% of peak levels. Qualified (25%) LPUE has been variable, although it is also well below levels of the late 1970s. After a major resurgence of qualified LPUE in 1986, it has returned to the level of ≈1.0 t/h recorded in recent years. Achievement of management yield targets has generally been poor, a result of overruns on the first seasonal opening (with a higher percentage of S. alutus) with consequent truncation of the second opening, and the opportunity to realize greater proportions of S. reedi in the catch.

9.7.3.2 Condition of the stock

No analytic assessments of this stock have been conducted and biological samples are extremely limited. Catch statistics are somewhat more stable than those for S. alutus in recent years, however landings have also been below target levels. Comparison of length frequency composition from recent commercial samples with that from simulated mortality rates (Fig. 9.16) suggests that total mortality rate experienced by this stock has been approximately 0.20. This rate, if accurate, would be above the target level of 0.16.

Depletion estimators suggest a pre-1977 biomass of ≈11,000 t, which may not be capable of supporting removals of 600 t/y, if M=0.08. Long-term sustainable yield may be closer to 450 t/y, if the typical Gulland (1961) relationship is valid for this stock. This result is in agreement with that of the length frequency comparisons.

9.7.3.3 Yield options

Yield options for the S. reedi stock in Area 5E(S) remain approximately the same as in 1987, although the range of values in Table 9.1 reflects the uncertainty associated with this assessment. Sustainable yield is estimated to range from 400-700 t.

9.7.4 West Queen Charlotte Islands (south of 54°) rougheye rockfish (Sebastes aleutianus)

9.7.4.1 Landing statistics

Landings and fishing effort for S. aleutianus in Area 5E(S) have been erratic since the inception of the fishery in 1977 (Table 9.17). Both nominal and qualified (25%) LPUE are presently well below (-50%) peak levels. There has been a major increase in directed fishing effort and landings during 1987, although total landings are only slightly above those of 1986.

9.7.4.2 Condition of the stock

A lack of any data except fishery statistics hampers assessment of this stock. We have no biological samples more recent than 1979, at which time the age range was extensive (18-72) and the estimated rate of natural mortality low (0.02-0.04) (Archibald et al. 1981). Vital statistics of this level imply relatively low yield potential. Fishery statistics provide little insight into present stock status. Estimated biomass in 1978 from regression of qualified LPUE on cumulative catch (see Section 9.7.2.2) was ≈2000 t. Equilibrium yield (F=M) from such a biomass would be 40-80 t. The low amount of directed effort (relative to the total fishery) implies that these estimates will be conservative.

9.7.4.3 Yield options

The estimated yield options for the *S. aleutianus* stock in Area 5E(S) reflect the uncertainty of our assessment (Table 9.1), although the generally low level of available yield from the area is recognized. Sustainable yield is estimated to range from 200-300 t.

9.7.5. West Coast Queen Charlotte Islands (south of 54°) redstripe rockfish (*Sebastes proriger*)

9.7.5.1 Landing statistics

Landings of *S. proriger* from Area 5E(S) have complemented those of the other slope rockfishes, over the 1980-1987 period (Table 9.18). Directed effort and landings remained low until 1985, when other slope quotas began to be fully subscribed early in the calendar year. For the past three years, directed effort (25% qualification) has exceeded 300 h/y and approached that for *S. alutus*, although qualified LPUE has decreased continuously.

9.7.5.2 Condition of the stock

Assessment information for this stock is limited. Size composition data (Figs. 9.17 and 9.18) suggest that mortality rate experienced by females (≈0.15-0.18) is within the appropriate range (0.16-0.20), although that for males (≈0.05) is lower than expected. The latter is difficult to account for on the basis of fishery results, unless the fishery is assumed to be sex-specific and/or significant grading of the catch by size is practiced. Examination of research samples suggests that male *S. proriger* are more strongly represented in catches than in landings (Nagtegaal and Farlinger 1980; Nagtegaal et al. 1980; Shaw and Archibald 1981). The long term effects of a female bias in landings are also suggested by the change in sex ratio of landings over time. For example, commercial samples of *S. proriger* in the late 1970s were comprised of 65-70% females, but had dropped to 56% by 1986, and to 40% in 1987. The strong sexual dimorphism of this species meant that these changes were also accompanied by a decrease in mean size; mean size in 1985 was 37.0 cm and 35.4 cm in 1987. Such evidence is only indirect observation of mortality rate and it is not possible to draw quantitative conclusions from it. Nonetheless, it would be prudent to heed this message and continue monitoring of sex ratio and mean size in the fishery and the population. The long-term effects of sex-biased fisheries are not clearly understood but the disproportionate reduction of reproductive effort, relative to the change in biomass, may cause equally disproportionate reductions in year-class success. Unfortunately, we have neither empirical evidence to provide guidance, nor sufficient understanding of the underlying biological process to permit realistic simulation for this species.

9.7.2.3 Yield options

If the decline in LPUE for recent landings (≈700 t/y) of *S. proriger* from Area 5E(S) is representative of stock condition, then it is unlikely this level is sustainable. Cluster analysis of landings from this area (Leaman and Nagtegaal 1987) suggests that the normal catch ratio of *S. proriger* to *S. alutus* is ≈0.217. Based on the yield options identified for *S. alutus*

(Table 9.1), the estimated level of sustainable yield for S. proriger is in the 80-150 t range. These figures may be conservative if the landing patterns, upon which the catch ratio is based, do not accurately reflect the catch of S. proriger. There has been no evidence of such market limitations in recent years, although they may have been operative in the late 1970s.

9.8.1 West Queen Charlotte Islands (north of 54°) rockfish (all Sebastes)

9.8.1.1 Introduction

The Langara Spit area (Area 5E(N)) has been the object of an experimental open-fishing project since the fall of 1983. The genesis of this experiment had roots in the longstanding conflict between management and the fishing industry, over the Department's estimates of biomass and available yield for rockfish stocks, for this and other areas. These estimates were derived from a variety of sources (trawl surveys, catch statistics, analytic models, biological parameters) and both parties had concerns about their validity. Rockfish Program staff began joint planning with industry in the fall of 1982, to establish an experimental program which would address the concerns previously expressed by both industry and Program staff (e.g. Leaman and Nagtegaal 1982). Program staff were concerned about the validity of both catch statistics and trawl surveys, while industry mistrusted some of the detailed analytic models employed by assessment biologists, and reasoned that their presence on the fishing grounds throughout the year gave them greater insight into stock conditions.

After some initial compromise on location and format, the Langara Spit area was chosen for the experiment and the duration was specified as 3-5y, to be followed by an equivalent period of conservative harvest. The objectives of the experiment were:

- to test biomass survey estimates (Program staff believed they could be seriously biased);
- to examine the stock-recruitment relationship relative to other stocks and fishing mortality;
- to validate ageing techniques through the injection of a large negative anomaly in the age spectrum of the stock;
- to examine movements;
- to develop estimates of mortality based on removals;
- to develop a detailed biological and fishery statistics database for use in analyses, e.g. fishing power estimation;
- to involve industry in both our research and management programs; and
- to provide concrete evidence of our desire to critically evaluate assessment results.

The experiment began with a joint industry-Department trawl survey (Leaman and Nagtegaal 1986) in July, 1983 and the manipulative portion of the experiment has continued to date. Execution of the experiment has not been satisfactory in terms of cooperation from the fleet (Leaman and Stanley 1987), but the Department has fulfilled its original commitment to the experiment.

9.8.1.2 Landing statistics

Annual landings have increased steadily since the inception of the experiment (Tables 9.19-9.23), although the pattern has not been consistent among target species. The major increment in landings occurred in 1984. With the exception of S. proriger (Table 9.20), the LPUE (nominal and qualified) for all species has dropped throughout the course of the experiment. For all species, present levels of qualified (25%) LPUE are less than 50% of peak levels. Redstripe rockfish is the sole species for which an increase in catch rate has been recorded (1986), however its LPUE has also decreased in 1987.

The species composition of the catch has changed over the course of the experiment (Table 9.23; Fig. 9.19) as the fleet has moved to alternative species (with lower catch rates) to supplement fishing on the major target, S. alutus.

9.8.1.3 Condition of the stock

The Langara Spit rockfish stocks continue to be in poor condition. Catch rates have decreased continuously since the initiation of the experimental fishery and the biological characteristics of the major target, S. alutus, indicate further depletion of the stock. Age composition samples illustrate that the fishery was based primarily upon fish <10 y old at the outset (Fig. 9.20). These ages are not fully recruited and have only been sexually mature for 1-2 y. The long-term implications of a fishery based on immature and recently-mature fish are obvious and serious. Size composition samples (Figs. 9.21 and 9.22) chronicle the depletion of cohorts that were present in the stock at the start of the experiment. For example, females in the 40-45 cm range formed the bulk of the catch in 1983/1984 but are almost completely absent by 1987 (Fig. 9.21). This is true whether abundance is considered in absolute or proportional terms. The progression of the shape of the length frequency distribution between 1983-1987 is exactly that predicted if existing cohorts were reduced to the point where the fishery was supported by recruitment. Further verification of depletion is afforded by consideration of catch rate, by size class. Catch rate of female fish >40 cm in 1983 was 212 fish/h, but had dropped to 78 fish/h by 1986. The comparable figures for both sexes are 273 fish/h and 111 fish/h in 1983 and 1986, respectively.

Comparison of length frequencies of commercial samples with those from simulation modelling of mortality rates (Stanley 1987b) reveals that S. alutus presently in the fishery have experienced total mortality rate in excess of 0.50 (Fig. 9.23), and close to 0.70. Clearly, such mortality is well above sustainable levels ($Z=0.10$).

The absolute level of rockfish biomass in the Langara Spit area is the subject of some uncertainty. Trawl surveys were conducted in 1979 and 1983. For some time (Leaman 1981; Leaman and Nagtegaal 1982, 1986) we have been expressing concern about the veracity of trawl surveys for rockfishes, and other aggregating forms. The prime dissatisfaction with such surveys is related to the dynamic diel behaviour of rockfishes and the consequent effects on accuracy and precision. Were the problem only the latter, improvements through sampling intensity might be realized. However, recent survey results (Leaman and Nagtegaal 1986; Nagtegaal et al. 1986) indicate that temporal variation in rockfish availability to survey gear can bias results to an extreme degree.

The 1983 survey of the Langara Spit area (Leaman and Nagtegaal 1986) produced biomass estimates within 15% of those from the 1979 survey of the same areas (Lapi and Richards 1981). S. alutus biomass from the comparable western portions of Langara Spit was estimated as ≈1000 t in 1983 and ≈1150 t in 1979. The 1979 survey covered the eastern Langara Spit and deeper waters more thoroughly than the 1983 survey, yet only for the eastern portion was there a gross difference in estimated biomass (140 vs 1070 t). The confidence interval for the 1983 survey was approximately ±67%. The two surveys were not strictly comparable because that in 1979 was a traditional stratified-random design while that in 1983 employed an encounter-response design (Leaman 1981). However, even given the design and areal coverage differences, it is clear that the commercial fishery has caught at least double the most optimistic survey biomass estimate, since 1983. These results are discouraging because, in spite of extensive investigation and development of rockfish surveys, the absolute estimates produced by even our best attempts are clearly biased. Whether any survey design will produce reliable estimates remains a topic for investigation. Based on our observations of rockfish behaviour, we are doubtful of success in such endeavour.

In summary, biological characteristics and fishery statistics of the major rockfish stocks in the Langara Spit area indicate continued high mortality rates and poor stock condition. Higher yields from this area could be realized through rehabilitative actions, although a return to maximum long-term yield could take 30-40 y, even with rigorous conservation.

9.8.1.4 Yield options

Yields of S. alutus in the order of 2000 t/y appear to have generated total mortality rates in the 0.6-0.7 range. If these figures are correct, then sustainable yields (Z≈0.10) should be in the range of 140-170 t. The upper limits of sustainability are unlikely to be more than twice this figure, and may be less if stock biomass has been reduced below levels giving rise to observed mortality rates. Similar calculations were applied to the average yield of 300 t/y for S. aleutianus. Yield options for S. reedi and S. proriger are simply guideline figures based on Francis' (1986) observations concerning the relationship between initial and long-term yields (see Section 9.5.1.3). Hence, sustainable yields are estimated to be ≈350-500 t and 500-700 t, respectively (Table 9.1). A cautionary note concerning the potential yield from these two species should be added. Both species were recorded by observers in catches by Japanese trawlers during 1977 (Leaman et al. 1978). The exact exploitation history for these species is therefore uncertain and yields identified here as those of initial fisheries may overestimate long-term yield, when used in this fashion. Characteristics of these two species in this area bear careful scrutiny in the future.

The experimental open-fishery component of this experiment is scheduled for termination at the end of 1987. It remains our view that the experimental design should be adhered to. However, managers have also been provided with a modification of the terminal phase of this experiment, for consideration prior to the beginning of the 1988 fishing year. That concept is presently under review.

Table 9.1. Yield options for slope rockfishes off the British Columbia coast for 1988.

		Yield options (t)		
Species	Area	Conservative	Sustainable (Low risk - High risk)	Non-sustainable
S. alutus	3C	<100	100 - 200	>200
S. proriger	3C	<200	200 - 1000	>1000
S. alutus	3D	<200	200 - 600	>600
S. reedi	3D/5A	<250	250 - 750	>750
S. proriger	3D/5A	<350	350 - 900	>900
S. alutus	5A/B	<700	700 - 1000	>1000
S. alutus	Moresby	<1900	1900 - 3000	>3000
S. reedi	Moresby	<160	160 - 500	>500
S. proriger	Moresby	<350	350 - 570	>570
S. alutus	5E(S)	<400	400 - 700	>700
S. reedi	5E(S)	<400	400 - 700	>700
S. aleutianus	5E(S)	<200	200 - 300	>300
S. proriger	5E(S)	<100	100 - 200	>200
Slope rockfish[a]				
Jan.-June		<300	300 - 600	>600
Sep.-Dec.		<600	600 - 1100	>1100
S. alutus	5E(N)	<150	150 - 170	>250
S. reedi	5E(N)	<350	350 - 500	>500
S. aleutianus	5E(N)	<50	50 - 100	>100
S. proriger	5E(S)	<500	500 - 700	>700
Slope rockfish[b]	5E(S)	<200	200 - 270	>270

[a] *S. alutus*, *S. reedi*, and *S. aleutianus*

[b] *S. alutus* and *S. aleutianus*

Table 9.2. Canadian landing statistics for Pacific ocean perch (*S. alutus*) off southwest Vancouver Island.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
	4.47	4.47	6.50	.688	4.28	4.50	.951
1968	.12	.12	6.30	.019	-	-	-
	-	-	-	-	-	-	-
1970	298.84	297.77	444.80	.669	273.11	293.20	.931
	206.99	201.14	552.00	.364	190.50	333.70	.571
1972	72.24	13.25	21.30	.622	12.67	14.30	.886
	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-
	5.46	5.46	166.50	.033	1.46	7.00	.209
1976	1.29	1.29	5.00	.258	.87	1.00	.870
	15.40	13.81	447.50	.031	8.67	42.30	.205
1978	48.88	48.57	57.80	.840	47.51	32.00	1.485
	80.62	79.91	147.10	.543	77.14	44.90	1.718
1980	285.59	284.77	448.20	.635	277.93	234.90	1.183
	381.54	364.99	750.80	.486	341.61	430.50	.794
1982	395.23	372.29	740.30	.503	342.56	430.70	.795
	373.97	179.30	348.30	.515	167.71	143.30	1.170
1984	406.17	317.39	481.90	.659	316.86	478.80	.662
	243.11	222.85	1079.60	.206	195.86	692.70	.283
1986	242.15	178.52	547.70	.326	140.49	185.10	.759
(a)	255.05	174.90	354.50	.493	163.67	213.80	.766

%qualification = % *S. alutus* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.3. Canadian landing statistics for redstripe rockfish (S. _proriger_) in Area 3C.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1980	.29	.29	1.00	.290	-	-	-
	12.76	12.76	10.50	1.215	9.32	4.30	2.167
1982	2.53	2.53	50.30	.050	2.42	1.80	1.344
	30.07	24.63	292.10	.084	11.66	31.30	.373
1984	34.57	11.01	331.10	.033	3.71	3.20	1.159
	61.01	44.16	406.50	.109	19.37	44.50	.435
1986	514.72	368.19	1724.10	.214	241.19	286.50	.842
(a)	172.24	128.86	508.20	.254	97.85	93.00	1.052

% qualification = % S. _proriger_ in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.4. Canadian landing statistics for Pacific ocean perch (*S. alutus*) off northwest Vancouver Island (Area 3D).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
	2.55	2.55	10.00	.255	2.55	10.00	.255
1968	41	.04	66.50	.001	-	-	-
	2.49	2.49	40.50	.061	1.26	12.50	.101
1970	5.38	5.38	150.60	.036	-	-	-
	11.39	11.39	82.00	.139	10.32	67.00	.154
1972	45.02	-	-	-	-	-	-
	-	-	-	-	-	-	-
1974	2.92	2.92	59.00	.049			-
	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
	1.13	1.13	7.30	.155	.14	4.00	.035
1978	7.05	4.48	18.90	.237	3.45	6.90	.500
	44.24	44.24	53.90	.821	43.89	40.80	1.076
1980	144.26	143.50	300.90	.477	126.80	190.10	.667
	165.97	165.97	353.40	.470	163.40	283.40	.577
1982	112.86	112.13	200.80	.558	109.92	124.30	.884
	463.33	214.39	574.30	.373	182.58	281.60	.648
1984	337.40	236.03	441.80	.534	231.60	353.30	.656
	312.69	262.51	506.40	.518	217.59	356.40	.611
1986	1045.95	658.23	815.00	.808	611.16	585.80	1.043
(a)	199.03	163.48	351.50	.465	129.31	87.50	1.478

%qualification = % *S. alutus* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.5. Canadian landing statistics for redstripe rockfish (*S. proriger*) in Queen Charlotte Sound - northwest Vancouver Island.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1980	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1982	2.58	2.58	121.00	.021	-	-	-
	40.76	38.25	139.40	.274	36.63	1.30	28.177
1984	49.37	15.66	281.90	.056	2.01	5.50	.365
	124.60	84.55	935.40	.090	45.27	197.00	.230
1986	1062.44	974.59	1932.80	.504	797.72	679.80	1.173
(a)	945.93	847.99	1134.30	.748	710.73	502.90	1.413

% qualification = % *S. proriger* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.6. Canadian landing statistics for yellowmouth rockfish (S. *reedi*) in Queen Charlotte Sound - northwest Vancouver Island.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
	5.35	5.35	31.50	.170	-	-	-
1972	-	-	-	-	-	-	-
	176.65	176.65	37.00	4.774	176.21	32.50	5.422
1974	78.91	78.91	23.00	3.431	78.91	23.00	3.431
	1.08	1.08	34.50	.031	-	-	-
1976	12.29	12.29	10.00	1.229	12.29	10.00	1.229
	335.89	335.89	466.00	.721	331.29	226.30	1.464
1978	16.54	16.54	110.00	.150	10.86	16.00	.679
	10.25	10.25	102.00	.100	6.49	9.70	.669
1980	27.92	27.92	97.50	.286	24.77	32.70	.757
	4.74	4.74	25.60	.185	.07	2.00	.035
1982	227.89	176.94	167.50	1.056	163.42	39.80	4.106
	628.09	460.12	501.50	.917	367.12	151.40	2.425
1984	458.27	201.59	405.10	.498	182.28	214.60	.849
	716.91	337.90	854.90	.395	292.01	204.50	1.428
1986	1208.37	944.84	1247.40	.757	817.10	546.10	1.496
(a)	1016.52	930.33	635.00	1.465	834.82	315.70	2.644

%qualification = necessary % S. *reedi* in catch for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.7. Total landings (foreign and domestic) of Pacific ocean perch (S. alutus), standardized LPUE and calculated total effort on the principal fishing grounds of Queen Charlotte Sound. (Fishery changed to winter fishery on spawning females 1983-1985.)

	Goose Island Gully			Mitchell's Gully		
Year	Total landings (t)	Standard LPUE (t/h)	Calculated effort (h)	Total landings (t)	Standard LPUE (t/h)	Calculated effort (h)
	1,890	.836	2,261	-	-	-
1960	1,679	.698	2,405	-	-	-
	1,199	.797	1,504	-	-	-
	1,838	1.161	1,583	-	-	-
	3,712	1.457	2,548	-	-	-
	3,450	1.134	3,042	57	-	-
1965	7,478	1.491	5,015	488	.780	626
	20,752	1.441	14,401	1,369	.815	1,680
	12,119	1.068	11,347	5,319	1.157	4,597
	10,213	1.045	9,773	2,556	1.137	2,248
	6,872	.763	9,007	2,945	.995	2,960
1970	6,489	.672	9,657	1,296	1.010	1,283
	3,455	.526	6,568	813	.954	852
	5,645	.829	6,809	995	.854	1,165
	3,755	.773	4,858	2,264	1.351	1,676
	7,269	.773	9,404	1,917	.974	1,968
1975	4,209	.507	8,302	1,151	.989	1,164
	2,442	.733	3,332	576	.673	856
	1,693	.66	2,565	256	.551	465
	865	.821	1,054	375	.817	459
	951	.799	1,190	480	.670	716
1980	1,226	.932	1,316	305	.862	354
	801	.76	1,054	680	4.474	152
	570	.514	1,110	286	2.648	108
	1,215	1.257	967	31	.929	33
	841	2.017	417	19	.594	32
1985	743	.475	1565	80	.149	537
	623	.534	1167	-	-	-
(a)	424	.339	1250	25	.332	74

(a) to 2/July/87

Table 9.8. Sensitivity coefficients for Goose Island Gully Pacific ocean perch simulations - 10 y horizon.

I. Yield					F. level					
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.1
Weight	0.0000	0.0000	3.0769	0.5000	1.3043	1.4285	0.9090	0.8333	0.7692	0.7317
Fecundity	-1.6666	-1.0000	2.3076	0.0000	0.4347	0.3571	-0.3030	0.0000	-0.2564	-0.2439
Partial recruitment	0.0000	0.0000	3.0769	0.5000	1.3043	1.0714	0.6060	0.5555	0.2564	0.2439
Stock recruitment	0.0000	0.0000	3.0769	0.5000	1.3043	1.0714	0.6060	0.5555	0.5128	0.4878
Initial recruitment	0.0000	0.0000	3.0769	0.5000	1.3043	1.0714	0.6060	0.5555	0.5128	0.4878
Recruitment variance	-1.6666	-1.0000	2.3076	0.0000	0.8695	0.7142	0.0000	0.2777	0.0000	0.0000
Initial N(J)	0.8333	0.1000	0.1153	0.0750	0.0869	0.0535	0 0606	0.0555	0.0512	0.0487
Natural mortality	-1.6666	-1.0000	1.5384	-0.5000	0.0000	0.0000	-0.6060	-0.5555	-0.5128	-0.7317
II. Biomass										
Weight	0.3727	-0.0177	2.6369	0.8743	1.1977	1.6184	0.7879	1.1614	0.6187	1.9191
Fecundity	-0.4538	-0.7992	1.6227	0.0182	0.3231	0.6936	-0.0750	0.2775	-0.2195	0.1486
Partial recruitment	-0.5996	-0.9946	1.3793	-0.2367	0.0190	0.3853	-0.3939	-0.0787	-0.5788	-0.2335
Stock recruitment	0.0810	-0.3019	2.2920	0.5828	0.9125	1.3487	0.5253	0.9055	0.3792	0.7855
Initial recruitment	-0.0162	-0.4085	2.1906	0.4918	0.7984	1.2331	0.4315	0.8070	0.2794	0.6794
Recruitment variance	-0.3403	-0.8348	1.7849	0.1275	0.4752	0.9633	0.1313	0.5118	-0.0399	0.3397
Initial N(J)	0.1223	0.1278	0.1369	0.1181	0.1121	0.1107	0.0994	0.0964	0.0978	0.0944
Natural mortality	-0.8589	-1.2078	1.1359	-0.4007	0.1330	0.2504	-0.4878	-0.1377	-0.6187	-0.2547

Table 9.9. Sensitivity coefficients for Goose Island Gully Pacific ocean perch simulations - 20 y horizon.

I. Yield	F. level									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.1
Weight	0.0000	0.9090	2.1428	1.1111	1.0000	1.3636	0.8333	0.8333	0.8333	0.8333
Fecundity	0.0000	0.0000	1.4285	0.5555	0.5000	0.9090	0.4166	0.4166	0.8333	0.4166
Partial recruitment	0.0000	0.0000	1.4285	0.5555	0.5000	0.4545	0.0000	0.0000	0.0000	-0.4166
Stock recruitment	0.0000	0.0000	2.1428	0.5555	1.0000	1.3636	0.8333	0.8333	1.2500	0.8333
Initial recruitment	0.0000	0.0000	1.4285	0.5555	0.5000	0.9090	0.4166	0.4166	0.4166	0.4166
Recruitment variance	-1.4285	0.0000	1.4285	0.0000	0.5000	0.9090	0.4166	0.4166	0.4166	0.0000
Initial N(j)	0.1428	0.1818	0.1785	0.1666	0.1500	0.1590	0.1458	0.1666	0.1666	0.1666
Natural mortality	-1.4258	-0.9090	0.0000	-0.5555	-0.5000	-0.4545	-0.8333	-0.8333	-0.8333	-0.8333
II. Biomass										
Weight	0.5922	0.3280	1.9659	0.0220	1.1245	1.4877	1.0693	0.8836	1.3333	0.3022
Fecundity	0.2164	0.0262	1.5944	0.7075	0.8304	1.1864	0.8118	0.6465	1.1428	0.1007
Partial recruitment	-0.4669	-0.8005	0.5572	-0.3773	-0.3633	-0.1318	-0.5544	-0.7758	-0.4523	-1.1405
Stock recruitment	0.6264	0.3937	2.0588	1.1320	1.2456	1.6572	1.2673	1.0991	1.5952	0.5289
Initial recruitment	0.1366	-0.1312	1.4705	0.5660	0.6574	1.0357	0.6336	0.4741	0.9047	-0.1007
Recruitment variance	-0.0113	-0.3543	1.3003	0.3930	0.5536	-0.9416	0.5544	0.3663	0.8571	-0.2015
Initial N(j)	0.1383	0.1463	0.1578	0.1360	0.1340	0.1327	0.1237	0.1217	0.1214	0.1171
Natural mortality	-0.9908	-1.2073	0.1857	-0.6132	-0.5190	-0.2071	-0.5544	-0.6896	-0.3095	-1.2090

Table 9.10. Sensitivity coefficients for Goose Island Gully Pacific ocean perch simulations - 30 y horizon.

I. Yield	F. level									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.1
Weight	0.8333	0.5263	2.1739	0.7142	1.7241	1.9354	1.2121	0.9090	0.6451	1.0714
Fecundity	0.8333	0.5263	2.1739	1.0714	1.7241	1.9354	1.5151	1.2121	0.9677	1.4285
Partial recruitment	0.0000	0.0000	1.3043	0.0000	0.6896	0.6451	0.0000	-0.6060	-0.9677	-0.3571
Stock recruitment	0.8333	0.5263	2.6086	1.0714	2.0689	2.2580	1.8181	1.2121	0.9677	1.7857
Initial recruitment	0.0000	0.0000	1.3043	0.3571	1.0344	1.2903	0.9090	0.3030	0.0000	0.7142
Recruitment variance	0.0000	0.0000	1.3043	0.3571	1.0344	1.2903	0.9090	0.3030	0.0000	0.7142
Initial N(j)	0.1250	0.1315	0.1304	0.1250	0.1206	0.1290	0.1212	0.1060	0.1129	0.1250
Natural mortality	-1.6666	-1.5789	0.0000	-1.0714	-0.3448	-0.3225	-0.6060	-1.2121	-1.2903	-1.0714
II. Biomass										
Weight	0.1708	0.2078	2.2327	0.4290	1.6373	1.6071	1.1456	0.7663	0.3719	1.7158
Fecundity	0.2496	0.3574	2.4213	0.6160	1.9215	1.9047	1.4893	1.1214	0.7439	2.1983
Partial recruitment	-0.9001	-1.0058	0.6184	-1.0891	-0.1894	-0.3422	-0.8510	-1.2897	-1.7286	-0.7506
Stock recruitment	0.4796	0.5735	2.7044	0.8580	2.1786	2.1875	1.7512	1.3644	0.9846	2.4664
Initial recruitment	-0.2956	-0.2660	1.6981	-0.0220	1.1366	1.1309	0.7037	0.3364	-0.0437	1.2064
Recruitment variance	-0.3088	-0.3574	1.6981	-0.0880	1.1772	1.2202	0.8183	0.3925	-0.0218	1.4209
Initial N(j)	0.1172	0.1280	0.1404	0.1221	0.1217	0.1220	0.1137	0.1140	0.1083	0.1152
Natural mortality	-1.6628	-1.5960	0.0733	-1.4081	-0.4059	-0.4166	-0.8019	-1.1214	-1.4442	-0.3217

Table 9.11. Sensitivity coefficients for Goose Island Gully Pacific ocean perch simulations - 100 y horizon.

I. Yield	F. level									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.1
Weight	1.0910	1.8709	0.8849	0.9649	1.2621	0.9090	1.0447	1.4000	0.2702	0.8333
Fecundity	0.0000	0.4301	0.7079	1.5789	2.6213	2.9545	4.0298	5.4000	4.3243	5.8373
Partial recruitment	0.9090	0.7526	0.0884	-0.2631	-0.5825	-1.4772	-1.7910	-2.0000	-3.2432	-3.3333
Stock recruitment	0.0000	0.4301	0.6194	1.3157	2.3300	2.5000	3.2835	4.6000	3.5135	5.0000
Initial recruitment	0.1818	0.2150	0.0000	0.1754	0.4854	0.1136	0.4477	0.8000	-0.2702	0.4166
Recruitment variance	0.3636	0.6451	0.4424	0.7017	1.1650	0.9090	1.1940	2.0000	0.5405	1.6666
Initial N(j)	0.0090	0.0107	0.0265	0.0350	0.0485	0.0625	0.0746	0.8000	0.0810	0.0833
Natural mortality	-0.9090	-1.0752	-1.5044	-1.7543	-1.7475	-2.2727	-2.2388	-2.2000	-3.2432	-2.9166
II. Biomass										
Weight	1.1520	1.0715	0.8434	1.0478	1.4880	0.6193	1.2944	1.1652	0.2914	1.3622
Fecundity	-0.0652	0.3098	0.5825	1.5323	2.7561	2.6945	4.2718	5.0178	4.6630	6.7801
Partial recruitment	-0.0111	-0.3043	-0.7962	-1.0391	-1.1464	-2.3186	-2.2734	-2.8537	-3.8433	-3.5603
Stock recruitment	-0.0047	0.3190	0.5218	1.3572	2.4380	2.2392	3.6326	4.2092	3.7522	0.7739
Initial recruitment	0.1559	0.1180	-0.0517	0.1984	0.6556	-0.0847	0.5987	0.5350	-0.2367	1.9814
Recruitment variance	0.4169	0.4739	0.3576	0.7005	1.3466	0.6299	1.4886	1.5695	0.6921	0.0897
Initial N(j)	0.0035	0.0106	0.0240	0.0310	0.0465	0.0577	0.0675	0.0731	0.0837	0.0897
Natural mortality	-0.7034	-1.0531	-1.4597	-1.5995	-1.4998	-2.3875	-2.0385	-2.3067	-3.0418	-2.3839

Table 9.12. Canadian landing statistics for Pacific ocean perch (S. alutus) in Moresby Gully.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1968	1.13	1.13	3.50	.323	1.13	3.50	.323
	.78	.78	23.80	.033	-	-	-
1970	27.35	25.58	594.30	.043	3.75	10.50	.357
	9.78	9.78	346.30	.028	1.62	8.50	.191
1972	13.18	13.18	567.10	.023	-	-	-
	37.93	34.21	672.90	.051	20.33	15.80	1.287
1974	36.30	34.97	595.50	.059	21.52	16.30	1.320
	116.53	107.25	1023.00	.105	93.64	91.30	1.026
1976	85.64	70.51	2185.00	.032	40.18	107.00	.376
	73.72	34.75	1788.00	.019	11.97	48.50	.247
1978	175.90	175.90	996.40	.177	126.63	82.60	1.533
	369.67	354.70	2046.00	.173	276.02	457.00	.604
1980	2544.95	2247.51	2259.20	.995	2232.59	1607.50	1.389
	2216.64	1523.91	1782.10	.855	1487.78	1009.20	1.474
1982	3625.58	2733.06	1846.00	1.481	2694.44	1282.80	2.100
	2219.99	1507.05	853.80	1.765	1503.57	668.70	2.248
1984	2055.02	1286.64	1578.70	.815	1269.42	693.10	1.832
	1967.25	1330.05	1593.70	.835	1275.72	740.60	1.723
1986	628.66	623.39	1239.70	.503	562.83	492.10	1.144
(a)	1207.29	1136.70	980.30	1.160	1108.62	716.30	1.548

%qualification = necessary % S. alutus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.13. Canadian landing statistics for redstripe rockfish (*S. proriger*) in Moresby Gully.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1980	19.32	19.32	193.00	.100	1.26	6.50	.194
	5.32	3.94	116.70	.034	-	-	-
1982	22.83	17.67	286.40	.062	2.12	5.50	.385
	19.94	15.72	107.80	.146	6.20	25.10	.247
1984	70.52	33.08	409.40	.081	18.52	41.20	.450
	180.83	152.72	544.40	.281	96.82	141.80	.683
1986	109.61	106.97	507.50	.211	51.29	125.00	.410
(a)	217.05	214.44	491.50	.436	128.75	170.60	.755

% qualification = % *S. proriger* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/7/87

Table 9.14. Canadian landing statistics for yellowmouth rockfish (*S. reedi*) in Moresby Gully.

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1978	91.94	91.94	54.30	1.693	84.65	45.20	1.873
	20.48	20.48	37.60	.545	-	-	-
1980	20.13	20.13	28.70	.701	1.50	5.50	.273
	109.67	40.95	116.60	.351	-	-	-
1982	417.32	325.15	711.60	.457	228.75	202.10	1.132
	202.04	78.24	239.70	.326	15.22	39.80	.382
1984	338.09	106.12	308.10	.344	34.73	50.20	.692
	232.01	177.51	342.90	.518	114.20	85.80	1.331
1986	100.28	100.28	226.80	.442	64.46	72.50	.889
(a)	34.70	23.48	247.90	.095	6.70	14.00	.479

% qualification = % *S. reedi* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.15. Canadian landing statistics for Pacific ocean perch (*S. alutus*) in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	78.78	78.78	59.00	1.335	78.78	59.00	1.335
	1549.42	1475.24	1041.50	1.416	1321.29	651.40	2.028
1978	2413.70	2346.93	1043.90	2.248	2255.89	724.40	3.114
	839.28	839.28	557.40	1.506	823.09	376.10	2.188
1980	876.96	472.90	496.20	.953	449.31	332.50	1.351
	599.21	432.73	235.70	1.836	412.99	172.50	2.394
1982	614.11	606.73	443.10	1.369	550.38	308.80	1.782
	835.17	762.67	629.80	1.211	721.46	403.80	1.787
1984	840.88	457.92	344.80	1.328	434.90	215.90	2.014
	828.61	603.93	691.50	.873	562.91	453.80	1.240
1986	641.91	473.78	733.50	.646	341.09	275.40	1.239
(a)	658.00	551.19	808.50	.682	488.07	453.30	1.077

% qualification = necessary % *S. alutus* in catch for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/7/87

Table 9.16. Canadian landing statistics for yellowmouth rockfish (*S. reedi*) in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
	1256.74	1256.74	583.00	2.156	1226.64	438.20	2.799
1978	1104.64	1104.64	600.40	1.840	858.89	296.30	2.899
	388.54	388.54	356.50	1.090	328.72	204.70	1.606
1980	499.91	477.23	321.50	1.484	477.23	321.50	1.484
	922.41	380.12	192.20	1.978	350.89	129.90	2.701
1982	414.39	351.87	335.90	1.048	307.98	191.90	1.605
	588.21	556.22	575.50	.966	501.10	356.70	1.405
1984	441.08	212.33	336.20	.632	169.75	178.90	.949
	495.77	344.95	609.80	.566	220.00	257.80	.853
1986	564.49	538.46	489.30	1.000	466.77	240.10	1.944
(a)	418.70	377.16	688.20	.548	303.44	262.00	1.158

% qualification = necessary % *S. reedi* in catch for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.17. Canadian landing statistics for rougheye rockfish (*S. aleutianus*) in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
	76.28	76.28	134.50	.567	74.69	66.00	1.132
1978	139.49	139.49	396.90	.351	105.71	118.30	.889
	192.09	192.09	347.70	.552	159.51	137.10	1.163
1980	51.42	51.42	60.00	.857	50.31	23.00	2.187
	9.93	9.93	46.20	.215	5.13	7.20	.713
1982	274.38	274.38	269.30	1.019	262.55	156.20	1.681
	74.16	61.37	324.10	.189	26.70	22.00	1.214
1984	100.85	73.37	215.30	.341	21.49	24.20	.888
	157.86	115.67	411.90	.281	77.52	178.30	.435
1986	268.77	165.56	371.60	.446	89.55	158.30	.566
(a)	296.06	260.48	696.70	.374	226.54	414.20	.547

% qualification = necessary % *S. aleutianus* in catch for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/7/87

Table 9.18. Canadian landing statistics for redstripe rockfish (*S. proriger*) in Area 5E (S).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1980	110.96	110.96	310.10	.358	64.70	77.90	.831
	132.63	81.01	148.60	.545	44.51	35.50	1.254
1982	33.55	31.10	210.70	.148	5.45	9.00	.606
	142.79	132.13	316.10	.418	76.13	96.60	.790
1984	148.45	85.11	212.30	.401	45.26	22.20	2.039
	918.73	763.12	708.10	1.078	713.17	439.80	1.622
1986	728.23	588.80	637.80	.923	459.01	318.00	1.443
(a)	510.47	488.77	606.60	.806	435.89	325.90	1.337

% qualification = % *S. proriger* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.19. Canadian landing statistics for Pacific ocean perch (S. alutus) in Area 5E (N).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
	1.42	1.42	19.70	.072	.70	2.30	.304
1978	22.22	22.22	151.10	.147	6.65	16.80	.396
	227.49	227.49	177.50	1.282	223.83	108.50	2.063
1980	84.56	84.56	119.30	.709	64.80	39.50	1.641
	109.22	63.58	32.40	1.962	53.15	24.10	2.205
1982	342.23	218.48	144.10	1.516	194.18	109.30	1.777
	291.98	226.43	401.80	.564	208.28	193.50	1.076
1984	2173.86	1819.93	1213.50	1.500	1779.38	980.00	1.816
	1921.21	1821.61	1908.70	.954	1712.09	1514.50	1.130
1986	2725.37	2658.69	2957.40	.899	2558.46	2319.30	1.103
(a)	961.86	961.86	1195.60	.804	933.16	1040.70	.897

% qualification = necessary % S. alutus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/7/87

Table 9.20. Canadian landing statistics for redstripe rockfish (S. proriger) in Area 5E (N).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1980	-	-	-	-	-	-	-
	.33	.33	4.90	.067	-	-	-
1982	13.27	6.43	35.30	.182	-	-	-
	18.44	3.14	17.50	.179	-	-	-
1984	110.85	108.31	552.10	.196	27.45	18.50	1.484
	258.99	258.99	1153.50	.225	93.53	98.30	.951
1986	716.62	711.98	2366.90	.301	474.57	314.00	1.511
(a)	195.44	195.44	835.70	.234	95.04	171.60	.554

% qualification = % S. proriger in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.21. Canadian landing statistics for yellowmouth rockfish (S. reedi) in Area 5E (N).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	16.86	16.86	69.90	.241	4.08	4.10	.995
1980	-	-	-	-	-	-	-
	2.34	2.34	4.90	.489	2.34	4.90	.478
1982	67.88	54.58	70.30	.776	52.36	36.50	1.435
	52.23	18.36	44.50	.413	3.48	9.00	.387
1984	72.84	63.05	468.30	.135	15.79	14.90	1.060
	179.88	173.60	1008.30	.172	55.12	40.50	1.351
1986	614.97	608.05	2151.90	.283	403.15	511.30	.788
(a)	48.10	48.10	590.40	.081	9.20	14.80	.622

% qualification = necessary % S. reedi in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/7/87

Table 9.22. Canadian landing statistics for rougheye rockfish (S. aleutianus) in Area 5E (N).

Year	Total landings	0% Qualification			25% Qualification		
		L	E	LPUE	L	E	LPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	13.99	13.99	139.50	.100	9.73	64.10	.152
1980	2.58	2.58	42.50	.061	-	-	-
	98.08	98.08	26.00	3.772	94.20	23.00	4.096
1982	69.09	69.09	74.40	.929	65.66	34.80	1.887
	127.46	84.01	271.50	.309	43.39	44.30	.979
1984	226.21	207.86	824.70	.252	93.50	134.30	.696
	453.67	453.25	1344.40	.337	310.64	397.20	.782
1986	460.81	430.00	1627.30	.264	264.83	338.90	.781
(a)	152.82	152.80	859.40	.178	52.55	87.50	.601

% qualification = % S. aleutianus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
LPUE = Landings per unit effort (t/h)
(a) to 2/July/87

Table 9.23. Catches and percentages of rockfish for the major species in the fishery for Minor Area 35, 1976-1987.

Year	Total rockfish (Sebastes)	*S. aleutianus*	*S. alutus*	*S. brevispinis*	*S. proriger*	*S. reedi*
1976	-	-	-	-	-	-
	5.51	-	1.42/25.77	-	-	-
1978	48.22	-	22.22/46.08	15.70/32.56	-	-
	287.27	13.99/ 4.87	227.49/79.19	7.77/ 2.70	4.76/ 1.66	16.86/ 5.87
1980	105.05	2.58/ 2.46	84.56/80.50	15.45/14.71	-	-/ .00
	376.13	98.08/26.08	109.22/29.04	2.26/ .60	.33/ .09	2.34/ .62
1982	691.53	69.09/ 9.99	342.23/49.49	37.57/ 5.43	13.27/ 1.92	67.88/ 9.82
	568.18	127.46/22.43	291.98/51.39	16.32/ 2.87	18.44/ 3.25	52.23/ 9.19
1984	2995.78	226.97/ 7.58	2186.33/72.98	248.34/ 8.29	110.85/ 3.70	72.80/ 2.43
	3230.61	465.37/14.41	1938.46/60.00	244.68/ 7.57	259.00/ 8.02	180.31/ 5.58
1986	4968.30	431.30/ 8.68	2727.20/54.89	165.80/ 3.34	707.30/14.24	620.40/12.49
(a)	1505.59	152.82/10.15	961.86/63.89	68.43/ 4.55	195.44/12.98	48.10/ 3.19

(a) to 2/July/87

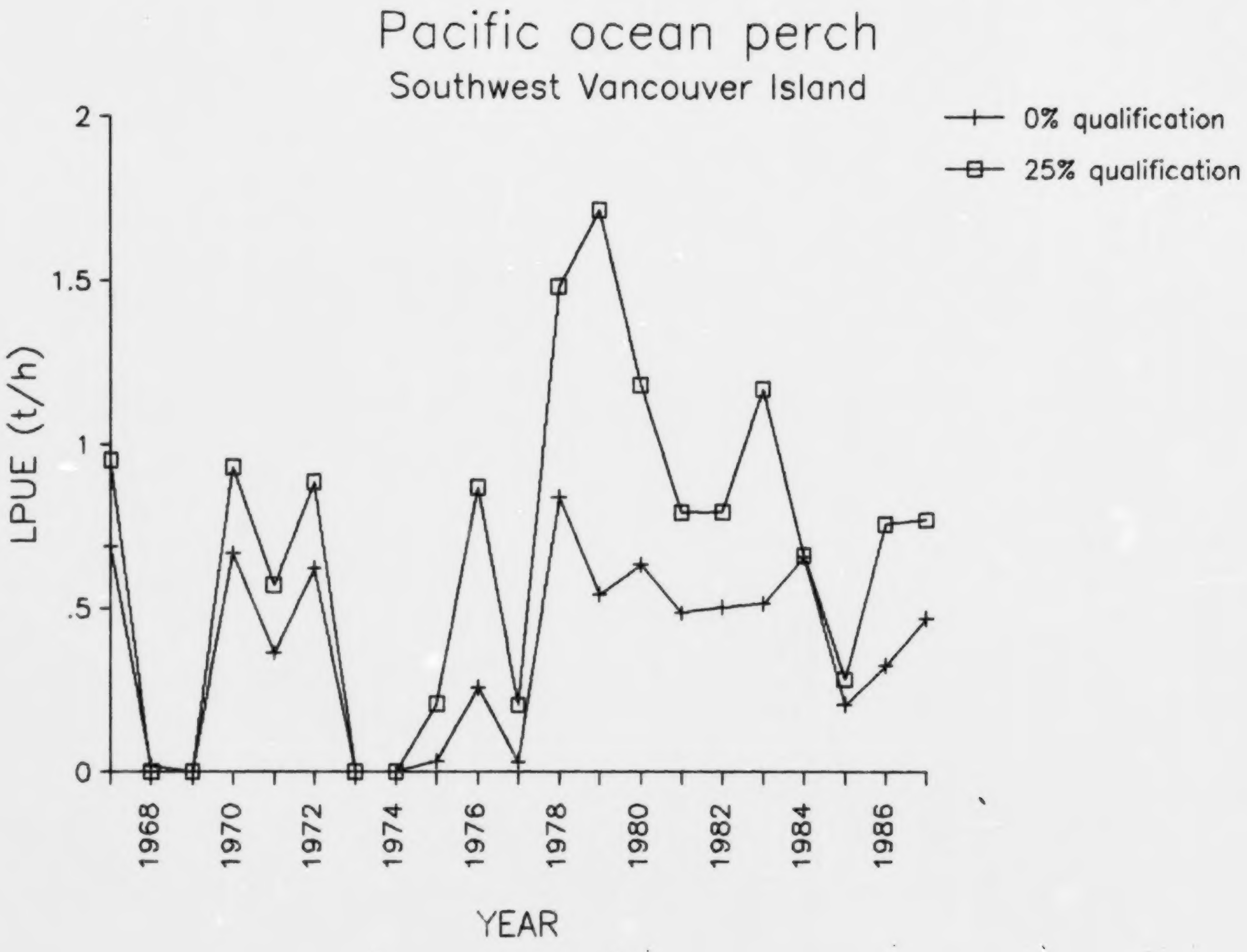

Fig. 9.1. Nominal and qualified (25%) landings per unit effort (t/h) for Pacific ocean perch (Sebastes alutus) off southwest Vancouver Island, 1967-1987.

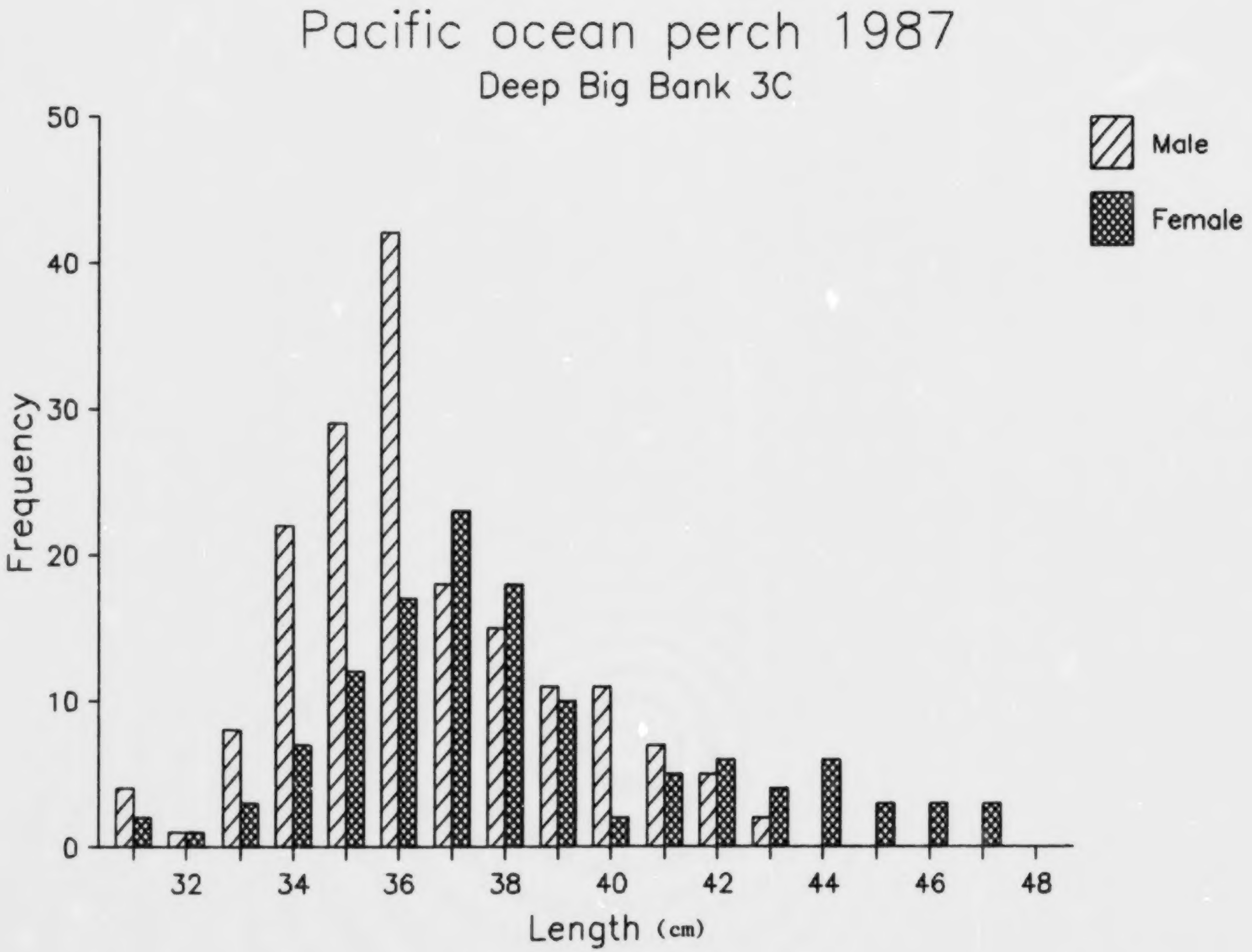

Fig. 9.2. Length frequency of Pacific ocean perch (S. alutus) off southwest Vancouver Island, 1987.

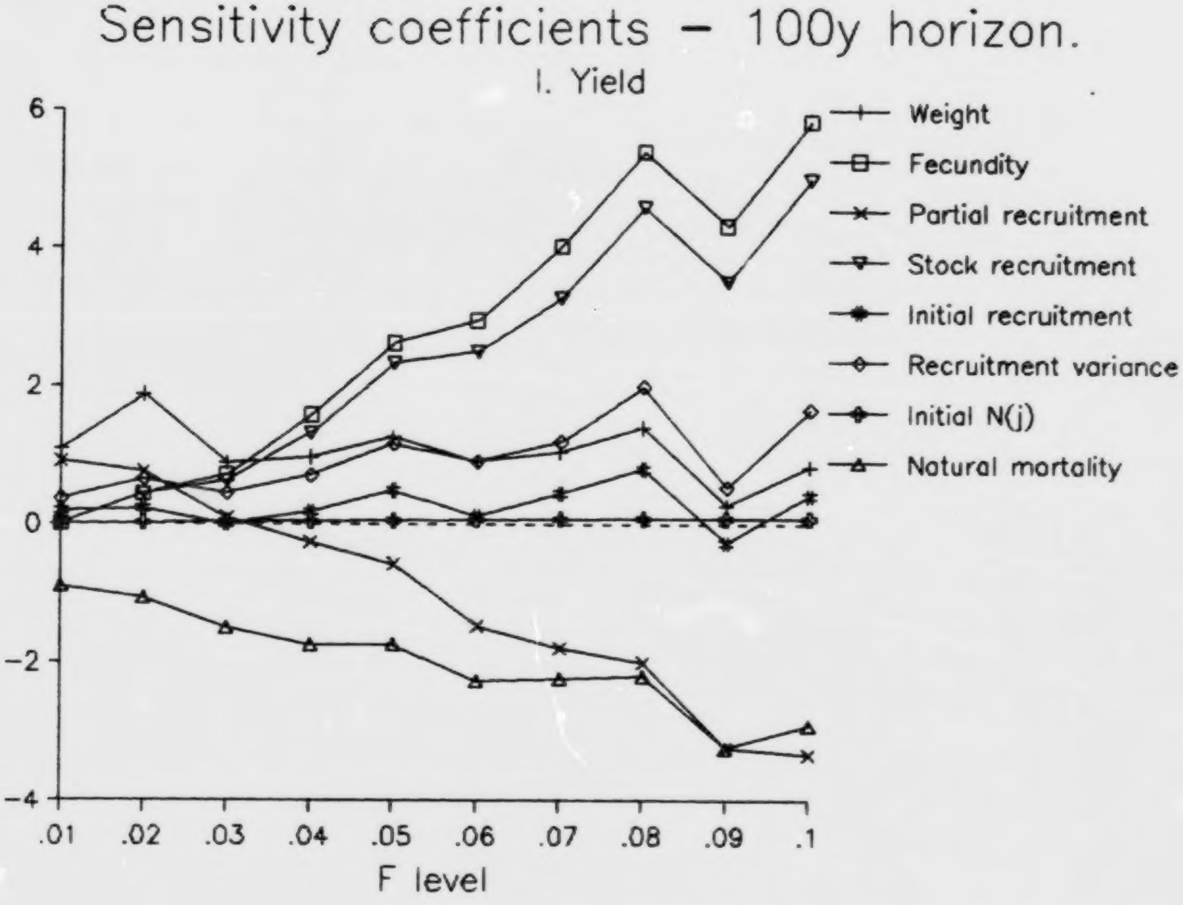

Fig. 9.3. Sensitivity to input parameters of 100 y simulations of yield from the Goose Island Gully Pacific ocean perch (*S. alutus*) stock, as a function of fishing mortality.

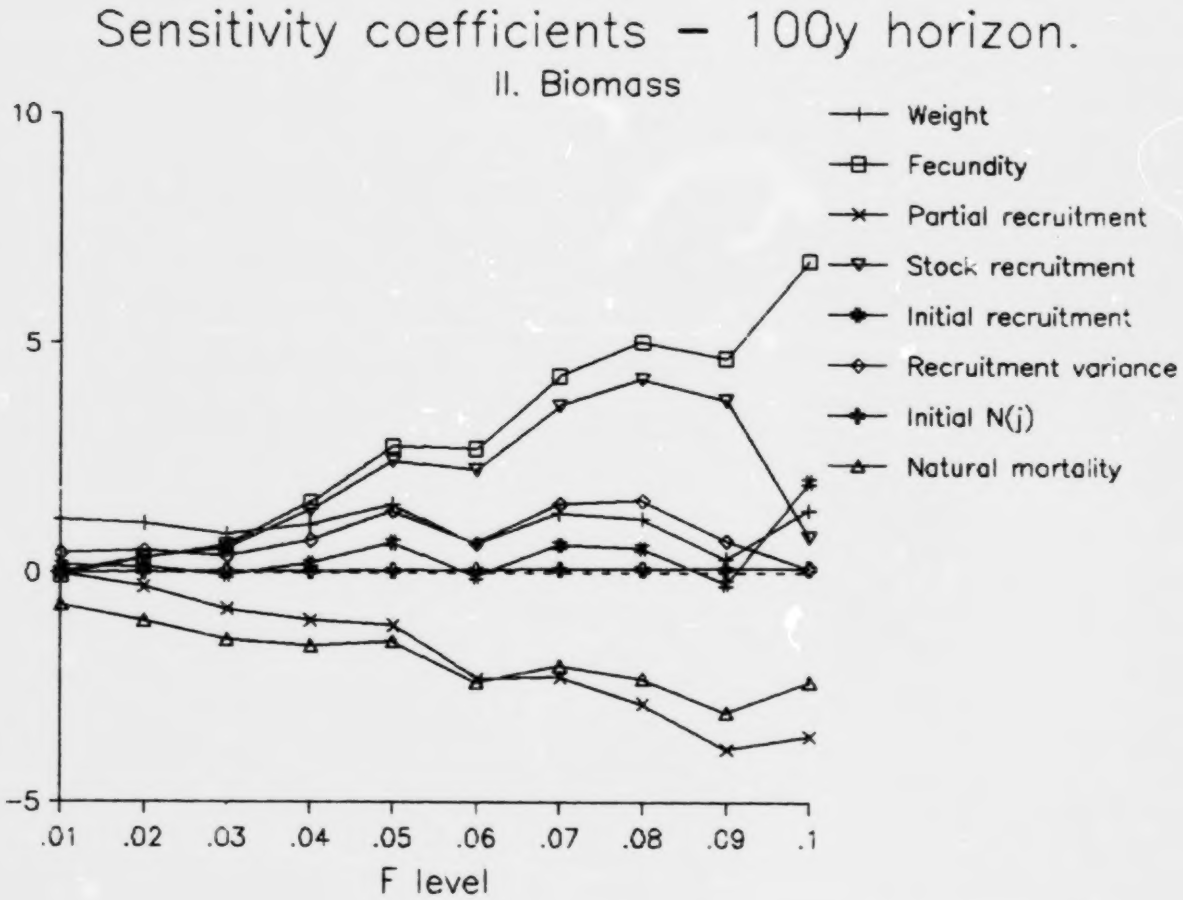

Fig. 9.4. Sensitivity to input parameters of 100 y simulations of biomass of the Goose Island Gully Pacific ocean perch (S. alutus) stock, as a function of fishing mortality (F).

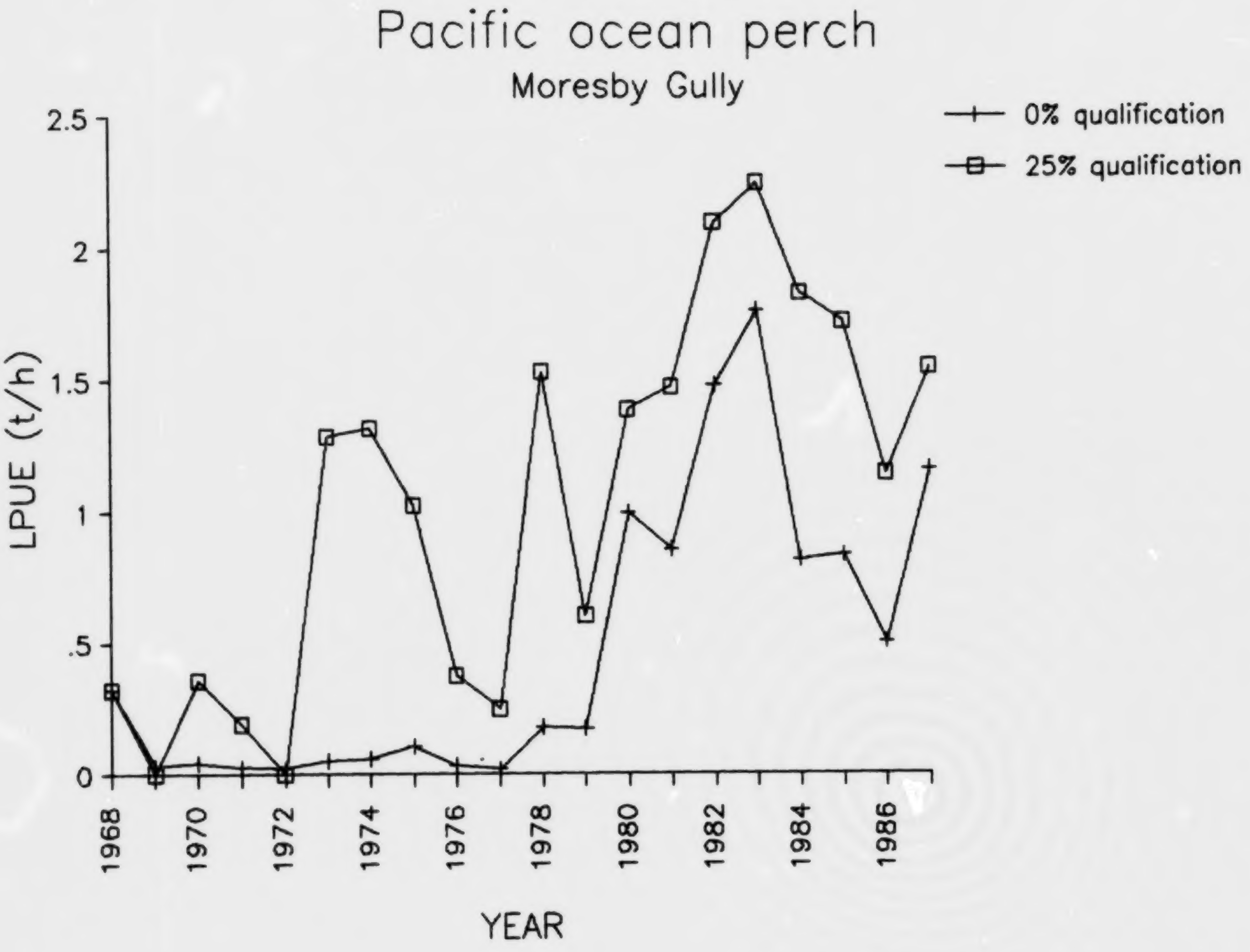

Fig. 9.5. Nominal and qualified (25%) landings per unit effort (t/h) for Pacific ocean perch (Sebastes alutus) in Moresby Gully, 1968-1987.

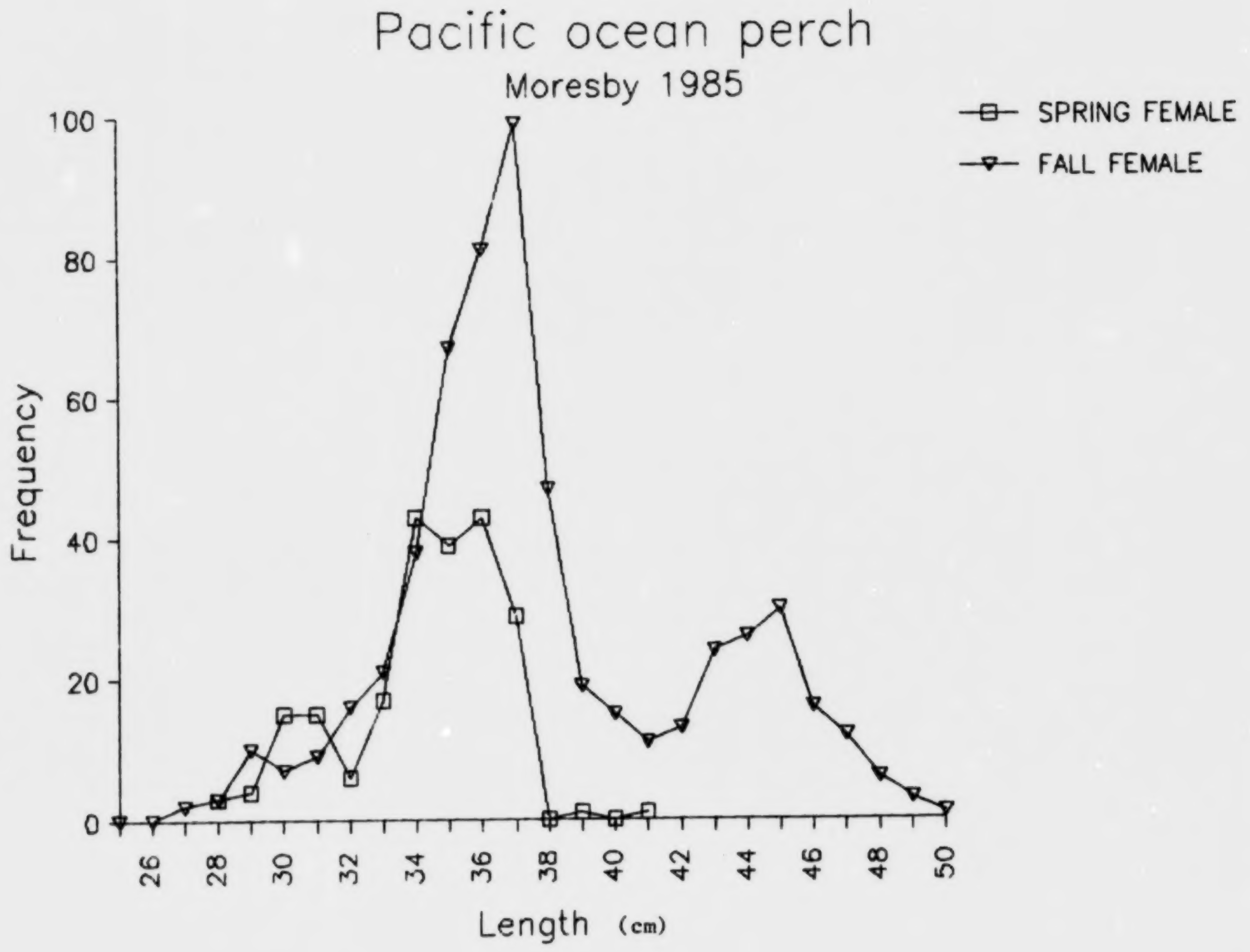

Fig. 9.6. Length frequencies of spring and fall samples of Pacific ocean perch (*S. alutus*) from Moresby Gully, 1985.

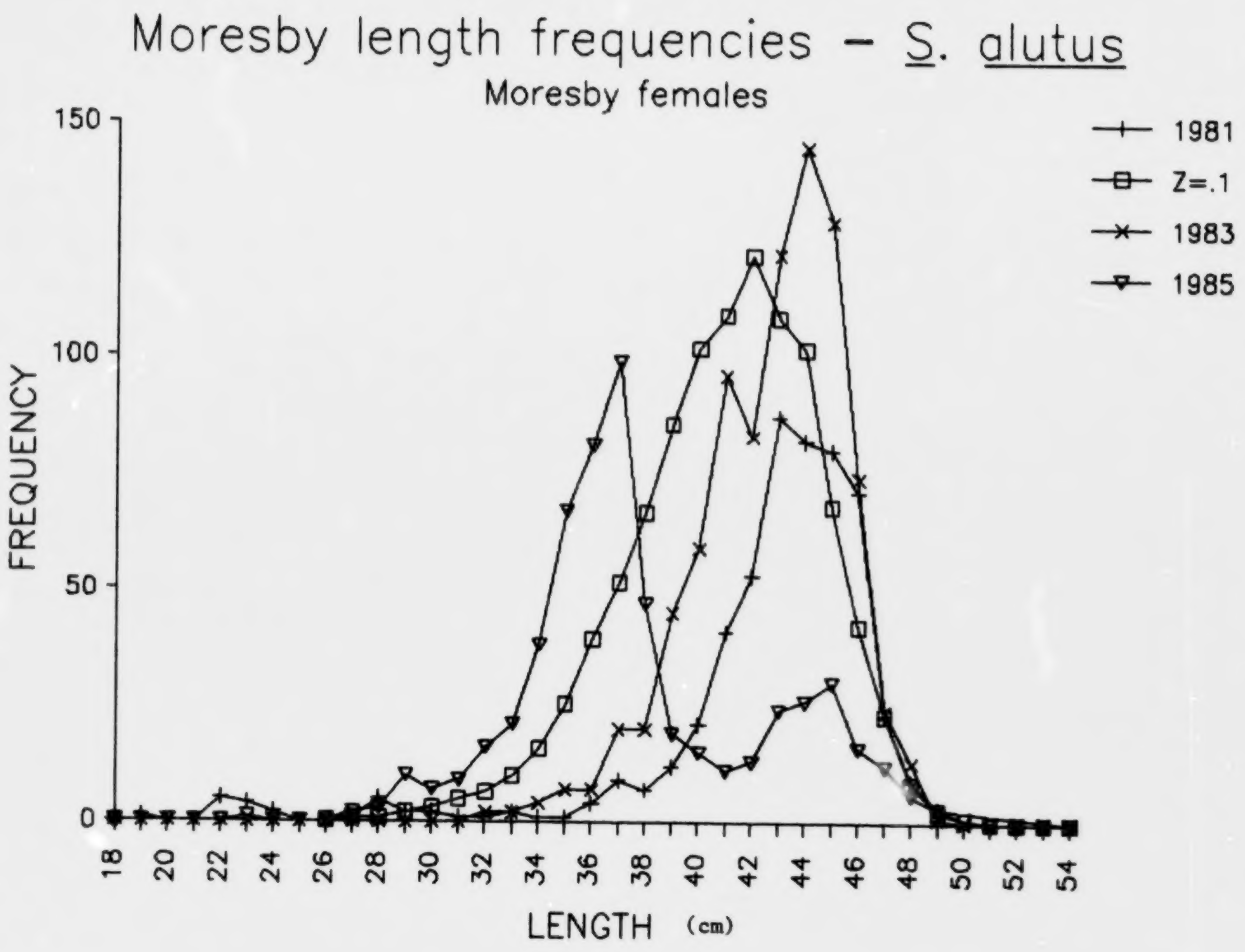

Fig. 9.7. Length frequencies of female Pacific ocean perch (S. alutus) from Moresby Gully in 1981, 1983, and 1985, compared with a frequency generated using a known mortality rate (Z=0.1).

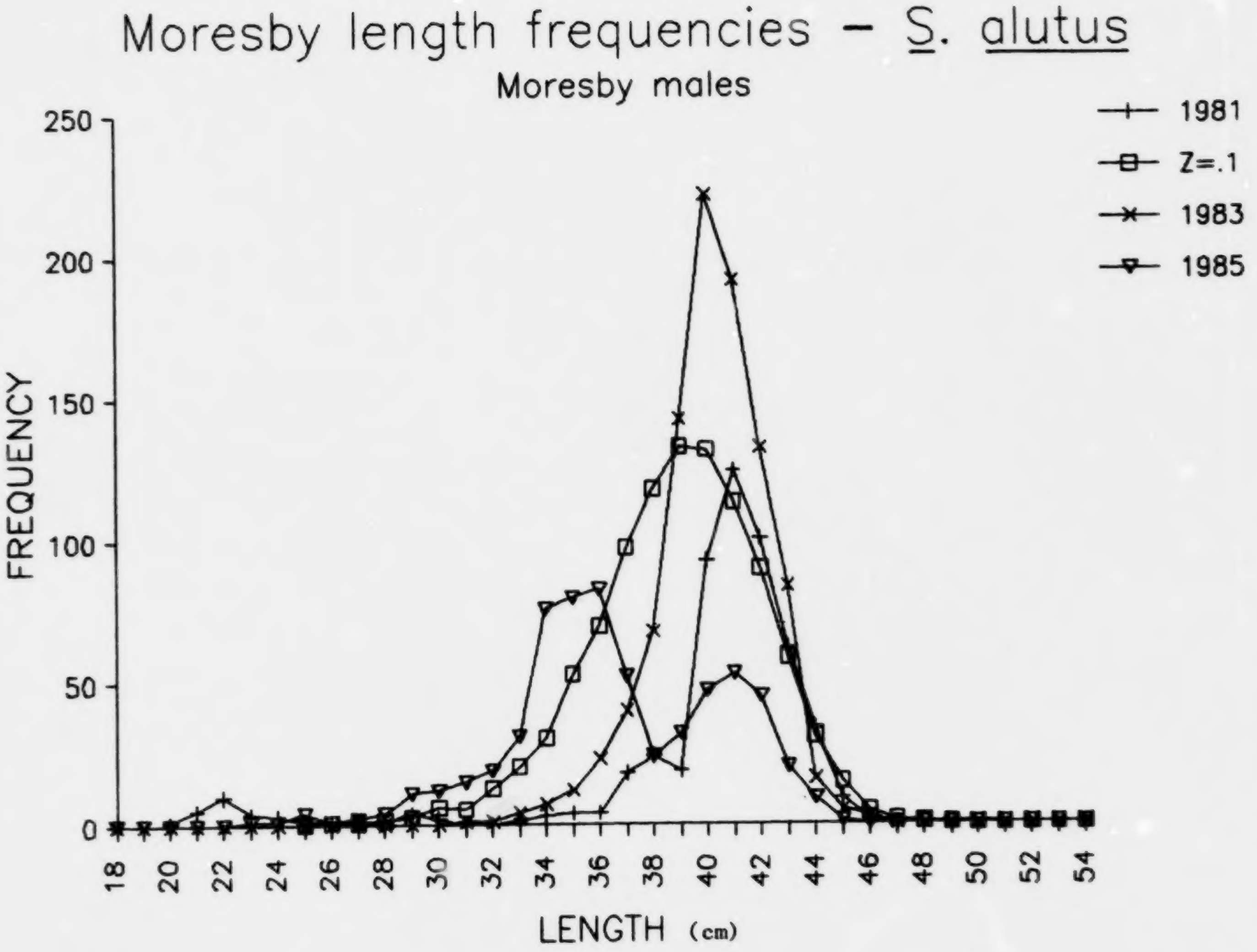

Fig. 9.8. Length frequencies of male Pacific ocean perch (S. alutus) from Moresby Gully in 1981, 1983, and 1985, compared with a frequency generated using a known mortality rate (Z=0.1).

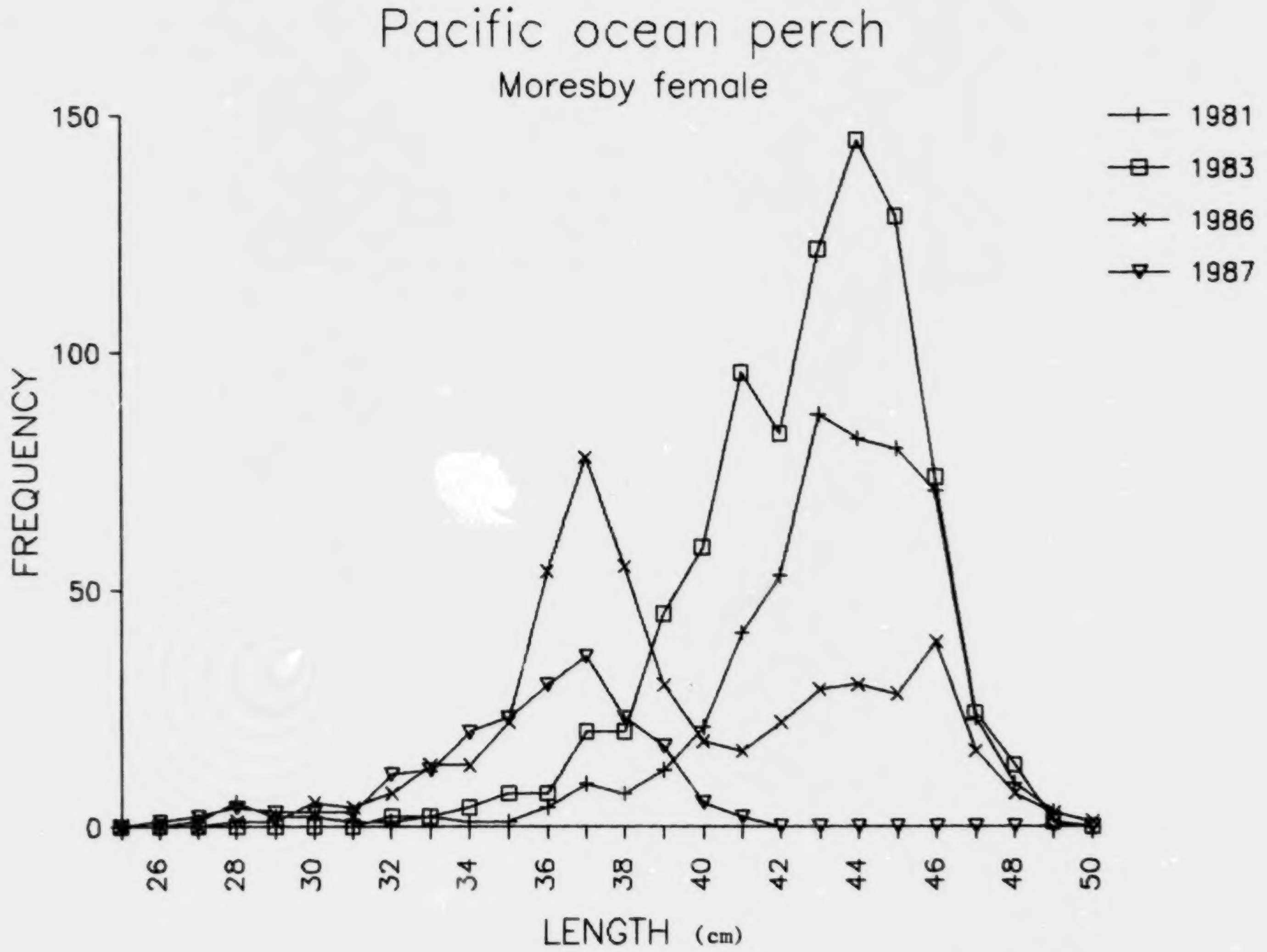

Fig. 9.9. Length frequencies of female Pacific ocean perch (S. alutus) from Moresby Gully in 1981, 1983, 1986, and 1987.

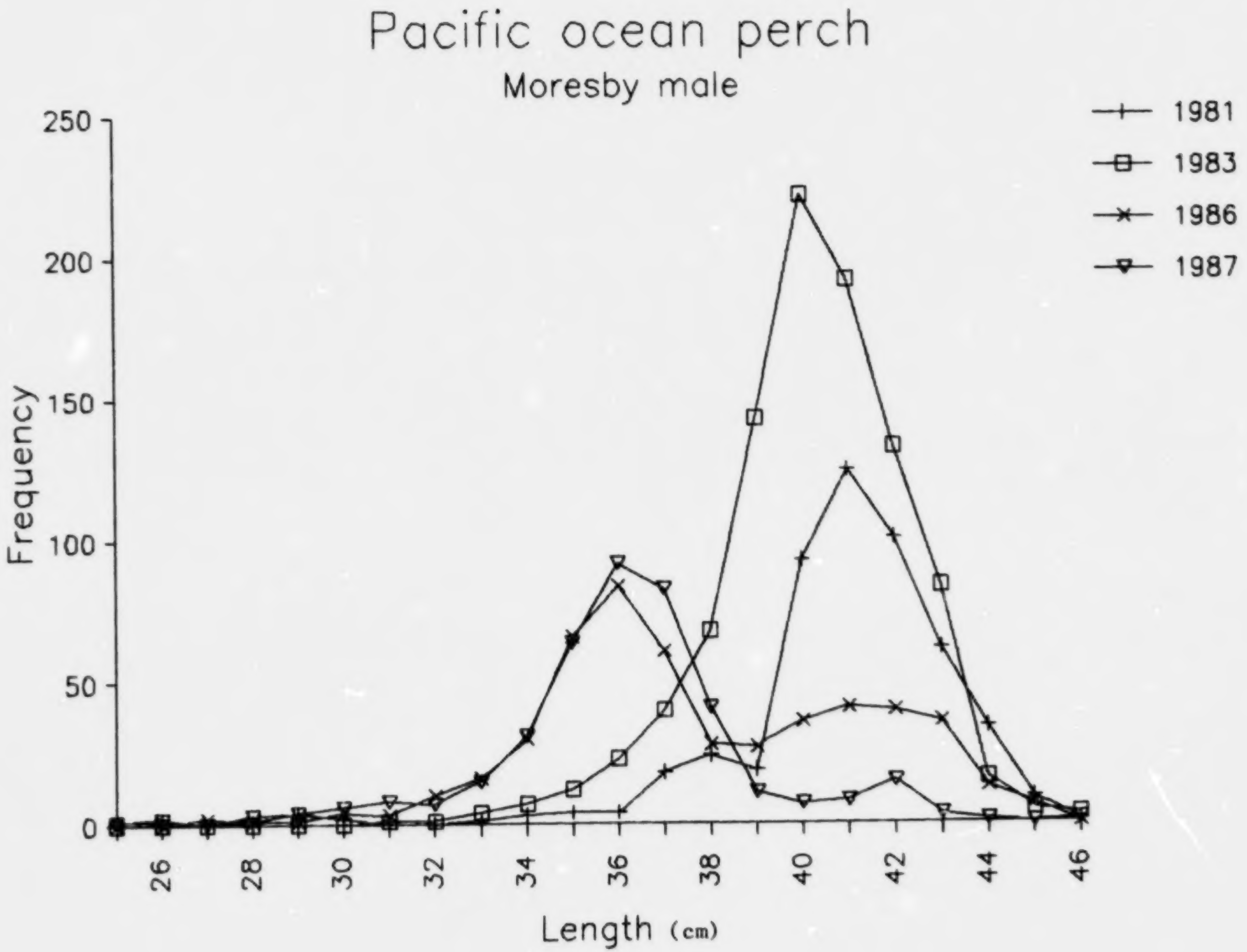

Fig. 9.10. Length frequencies of male Pacific ocean perch (S. alutus) from Moresby Gully in 1981, 1983, 1986, and 1987.

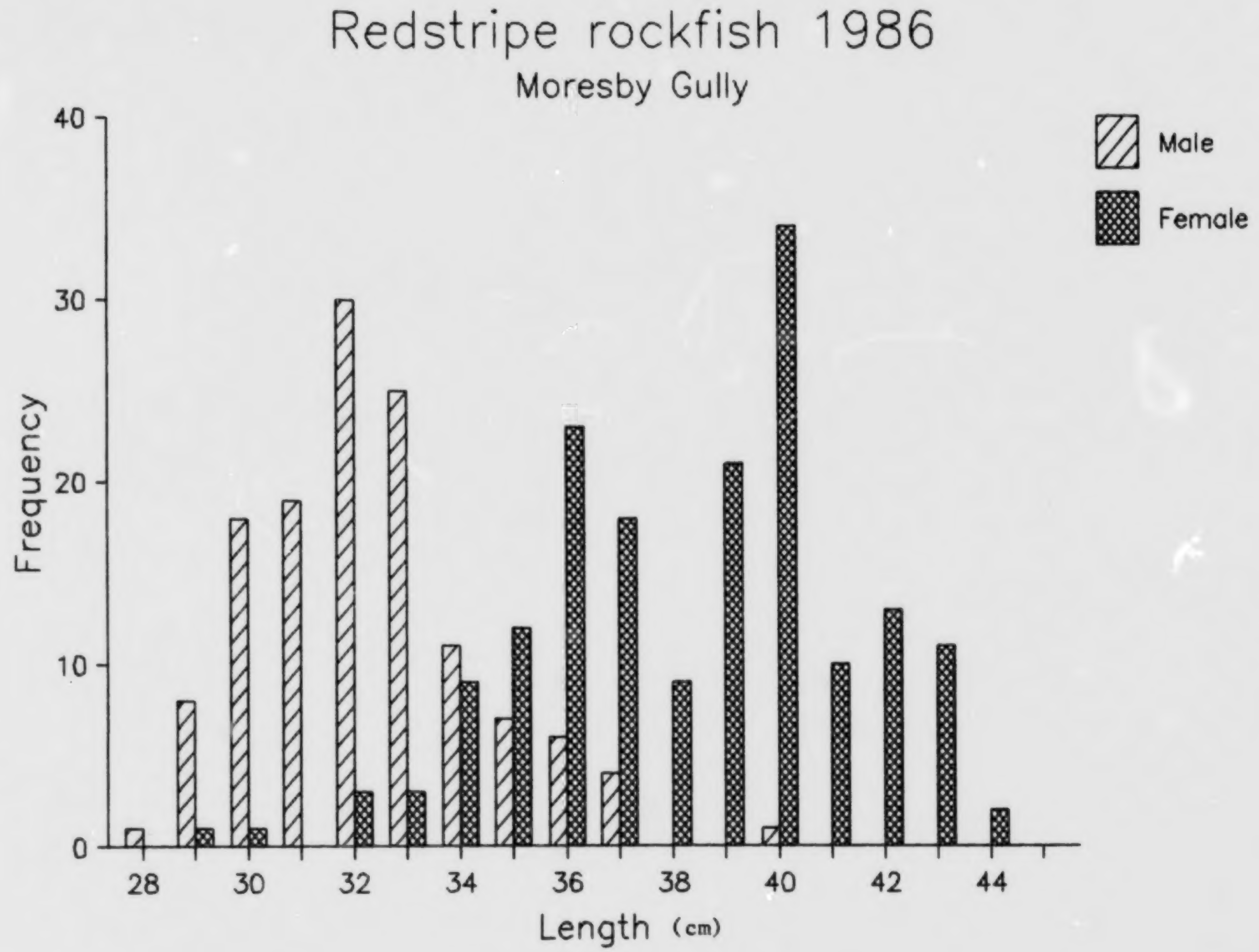

Fig. 9.11. Length frequencies of male and female redstripe rockfish in Moresby Gully, 1986.

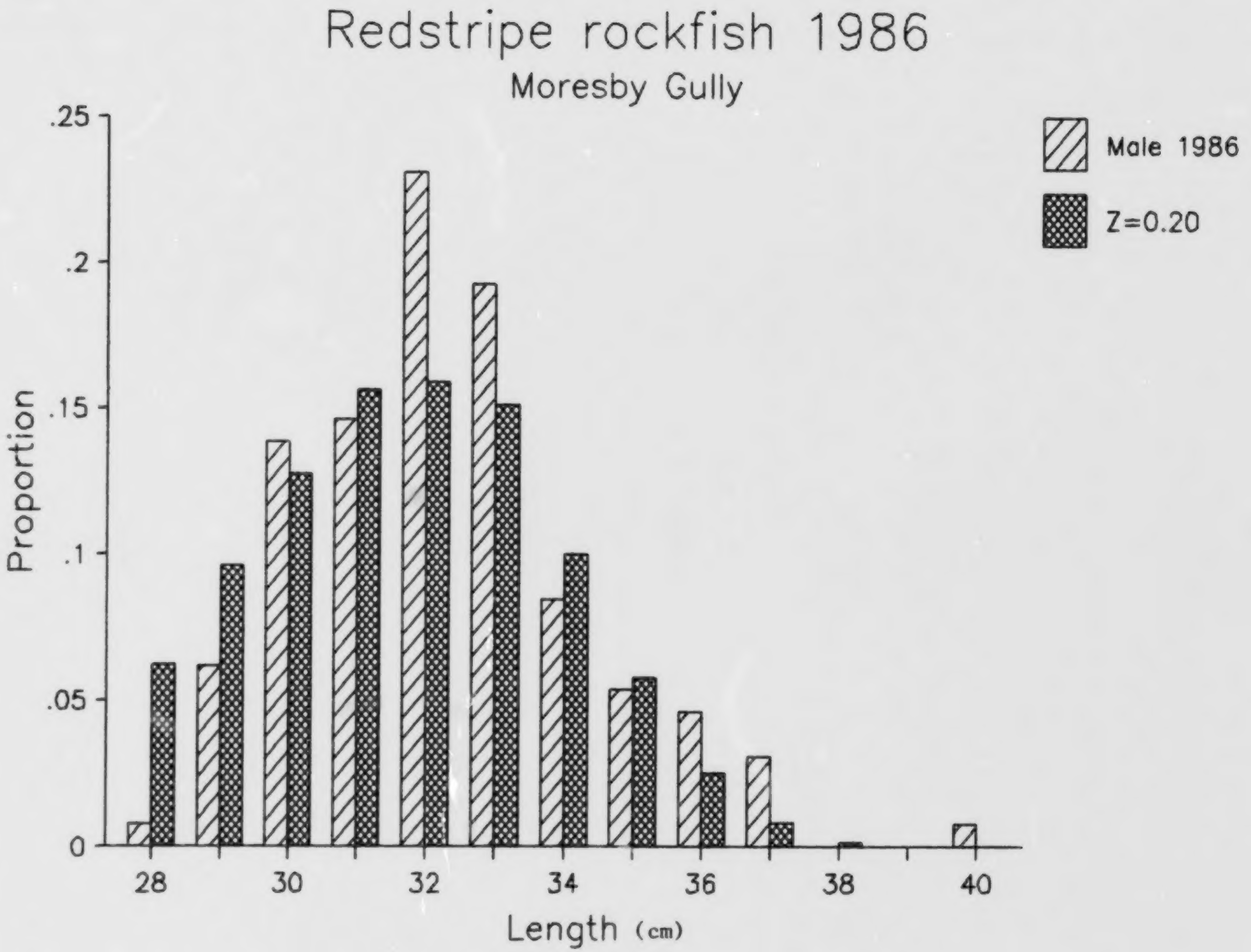

Fig. 9.12. Length frequency of male redstripe rockfish (S. proriger) from Moresby Gully in 1986, compared with a frequency generated using a known mortality rate (Z=0.20).

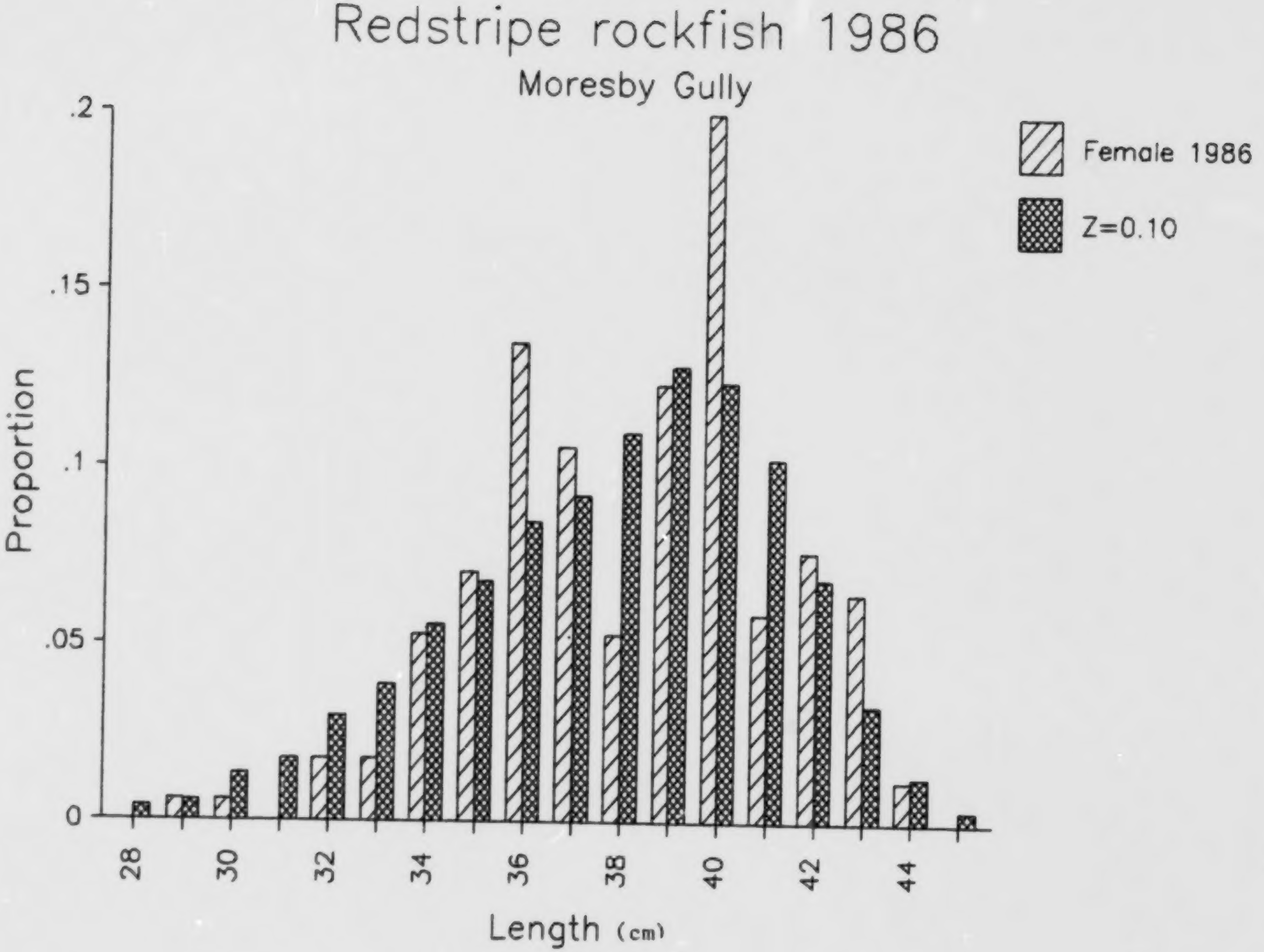

Fig. 9.13. Length frequency of female redstripe rockfish (S. proriger) from Moresby Gully in 1986, compared with a frequency generated using a known mortality rate (Z=0.10).

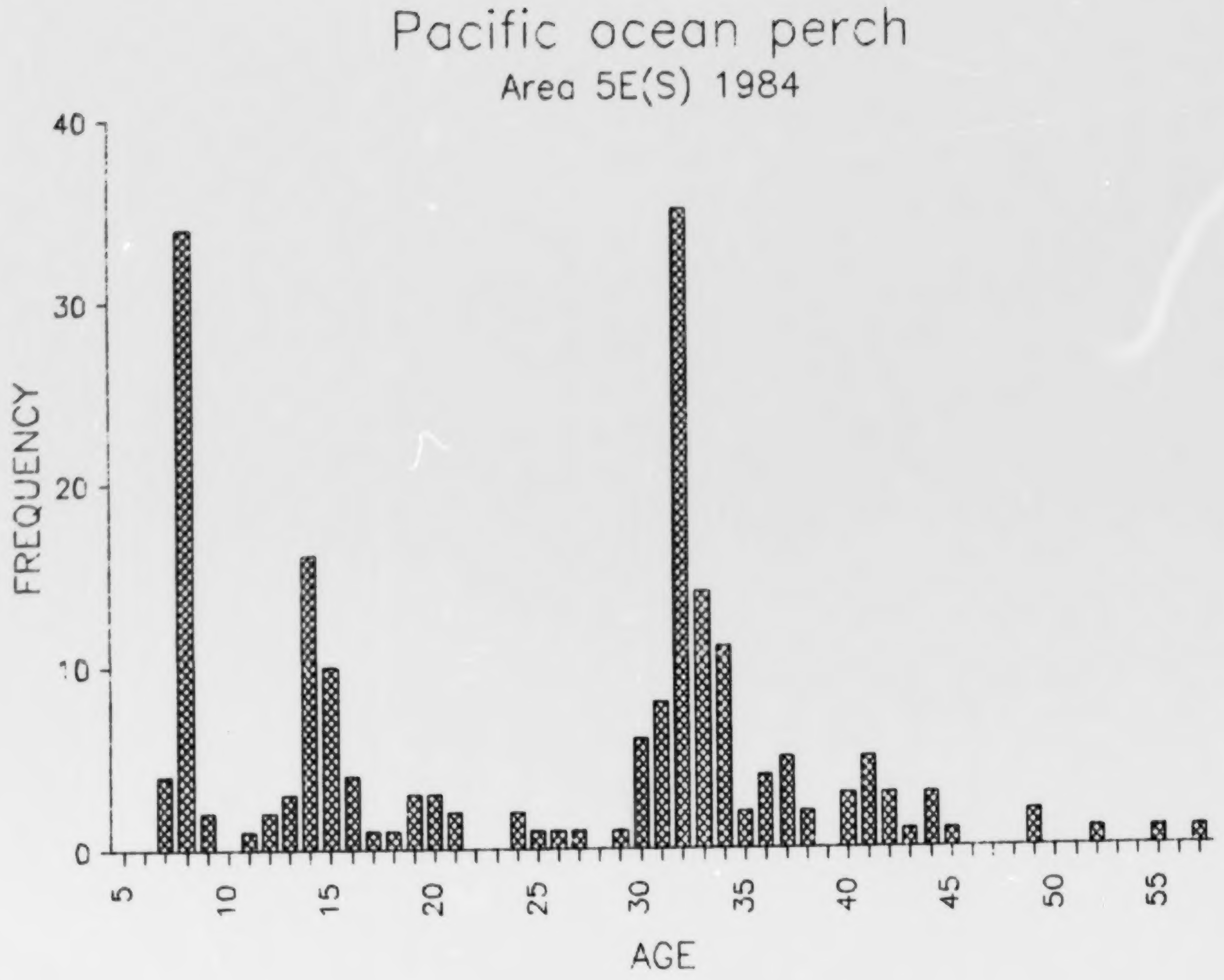

Fig. 9.14. Age frequency of Pacific ocean perch (S. alutus) off the west coast of the Queen Charlotte Islands (south of 54°N), 1984.

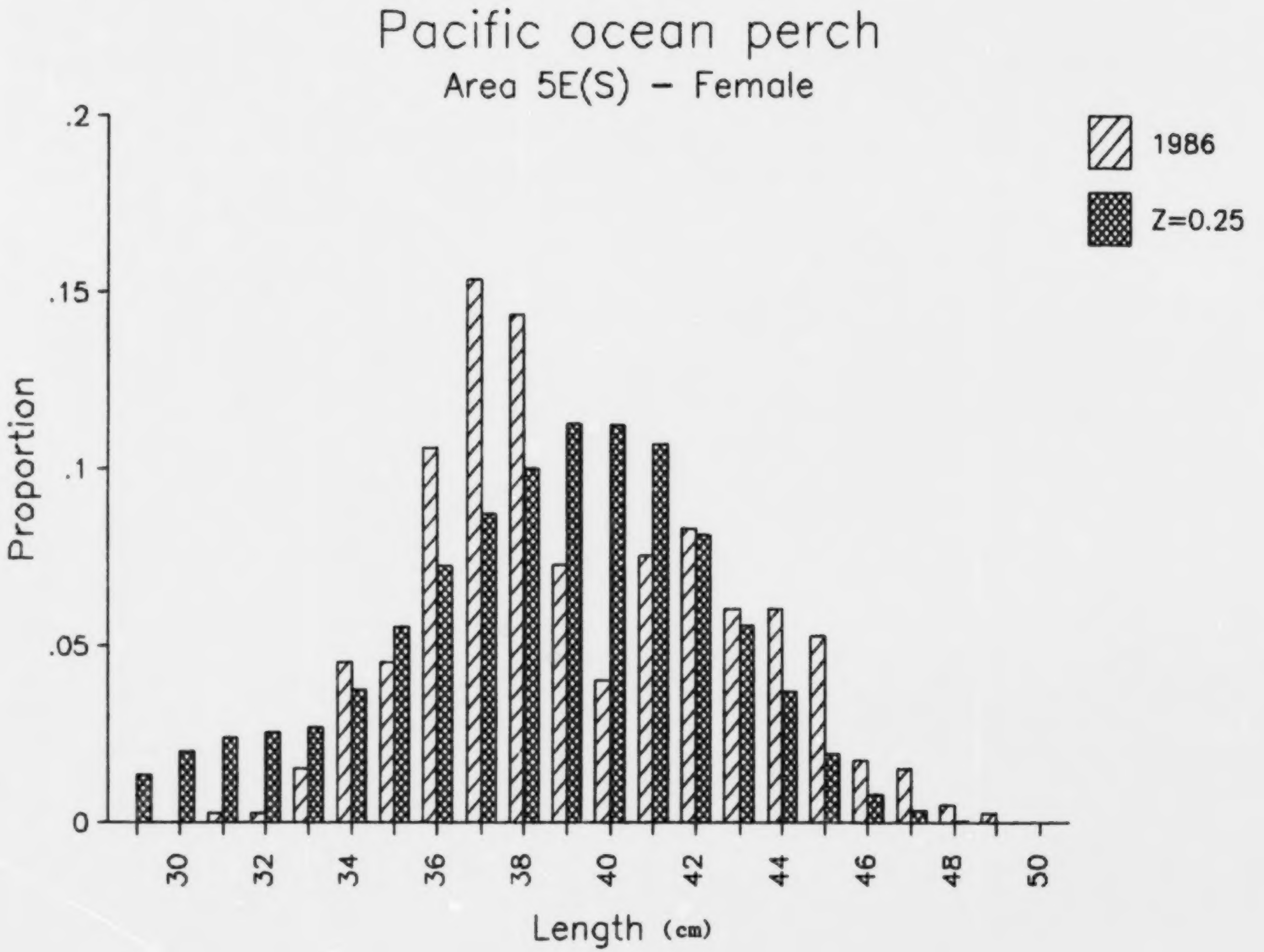

Fig. 9.15. Length frequency of female Pacific ocean perch (S. alutus) off the west coast of the Queen Charlotte Islands (south of 54^{o}N) in 1986, compared with a frequency generated using a known mortality rate (Z=0.25).

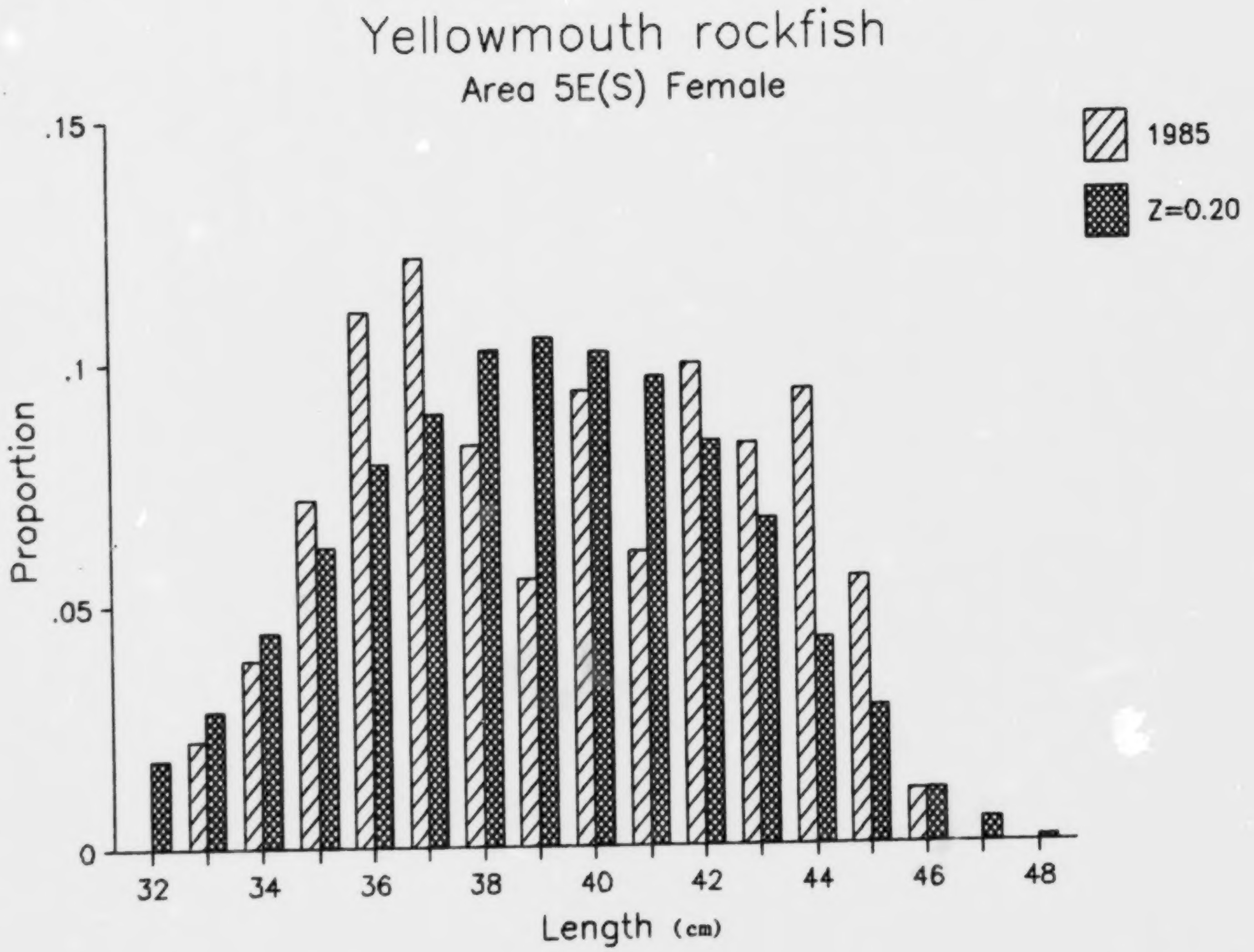

Fig. 9.16. Length frequency of female yellowmouth rockfish (S. reedi) off the west coast of the Queen Charlotte Islands (south of 54°N) in 1986, compared with a frequency generated using a known mortality rate (Z=0.20).

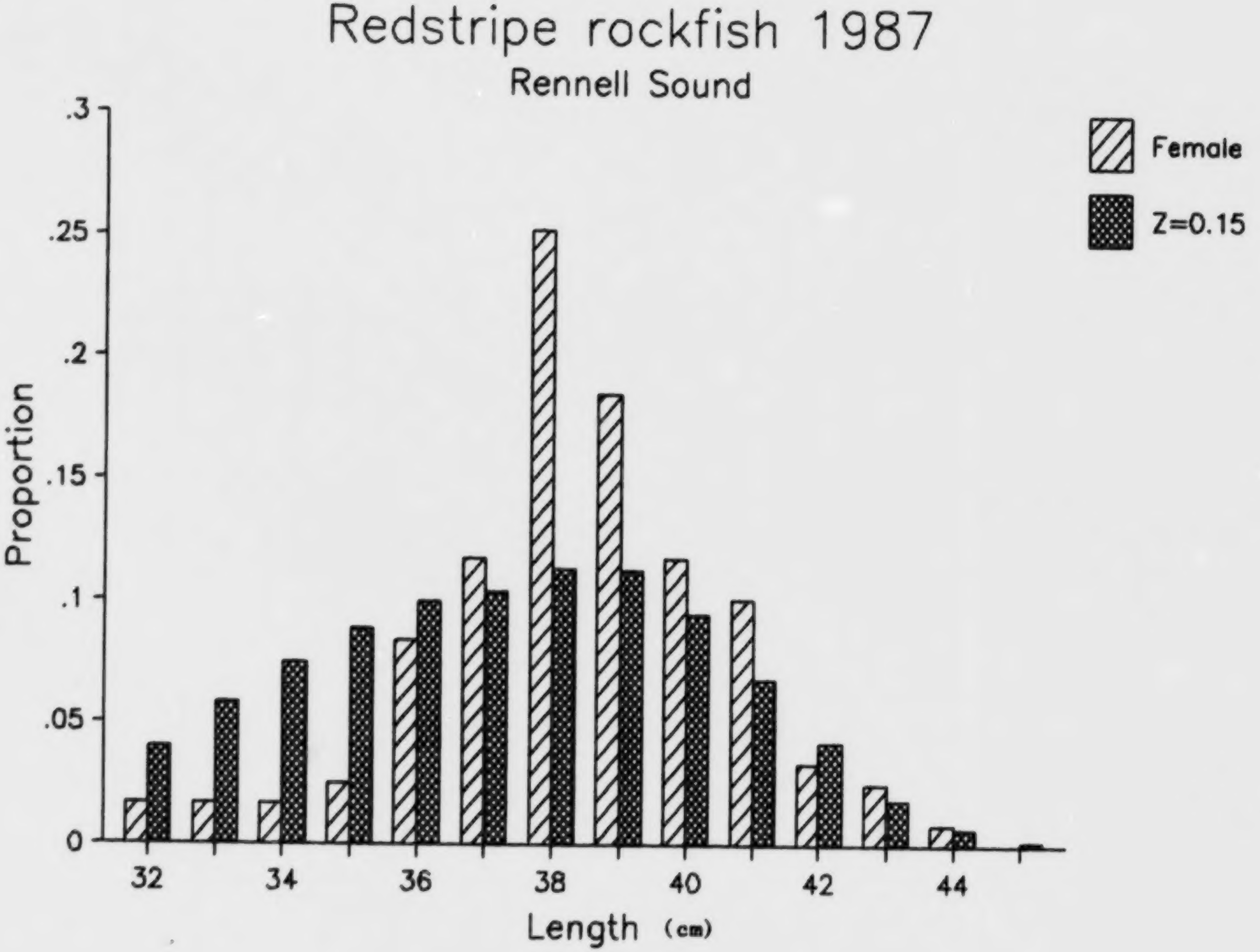

Fig. 9.17. Length frequency of female redstripe rockfish (S. proriger) off the west coast of the Queen Charlotte Islands (Rennell Sound) in 1987, compared with a frequency generated using a known mortality rate (Z=0.15).

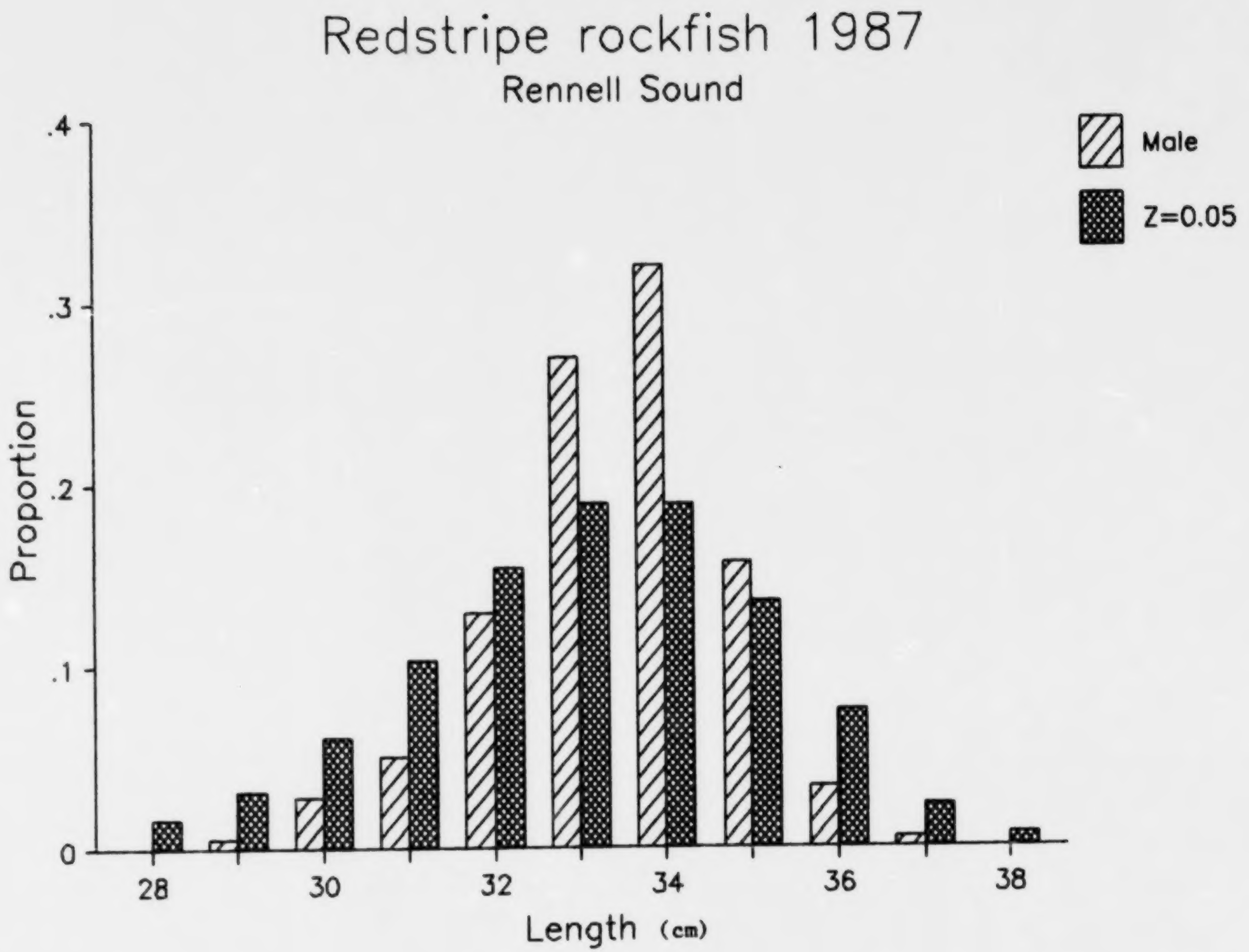

Fig. 9.18. Length frequency of male redstripe rockfish (S. proriger) off the west coast of the Queen Charlotte Islands (Rennell Sound) in 1987, compared with a frequency generated using a known mortality rate (Z=0.05).

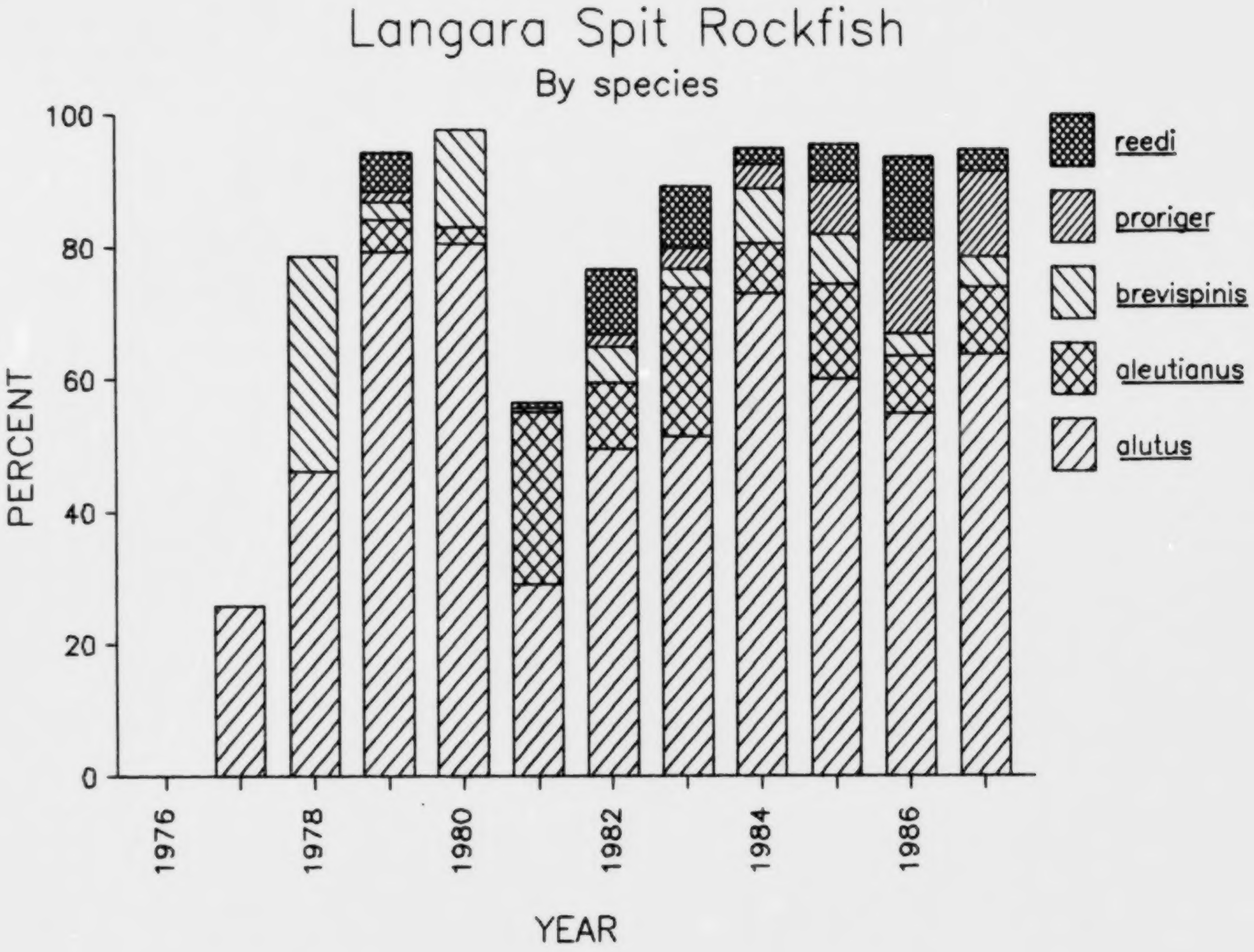

Fig. 9.19. Composition of rockfish catches in the Area 5E(N) (Langara Spit) fishery, by major species, 1976-1987.

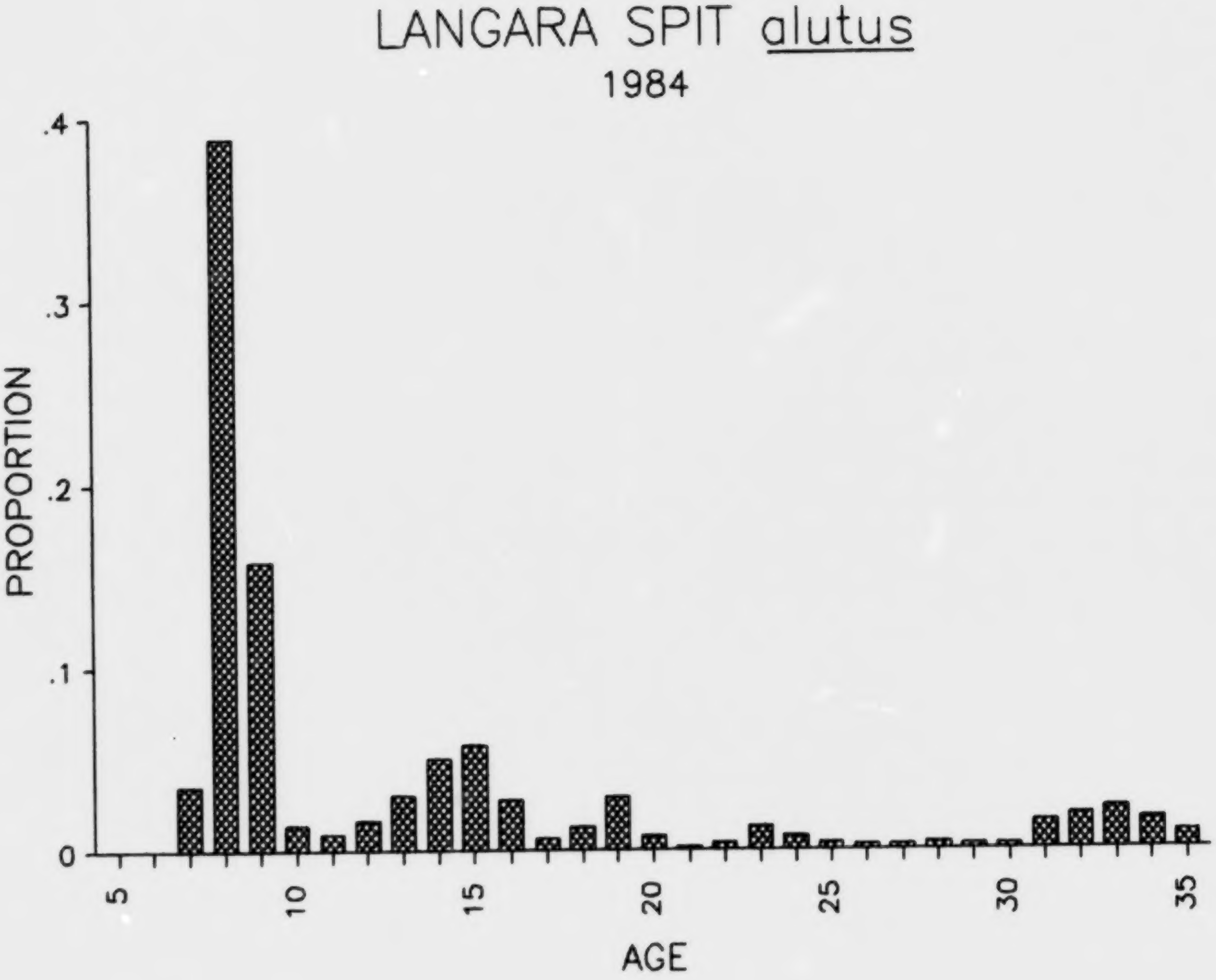

Fig. 9.20. Age frequency of Pacific ocean perch (S. alutus) in the Area 5E(N) fishery, in 1984.

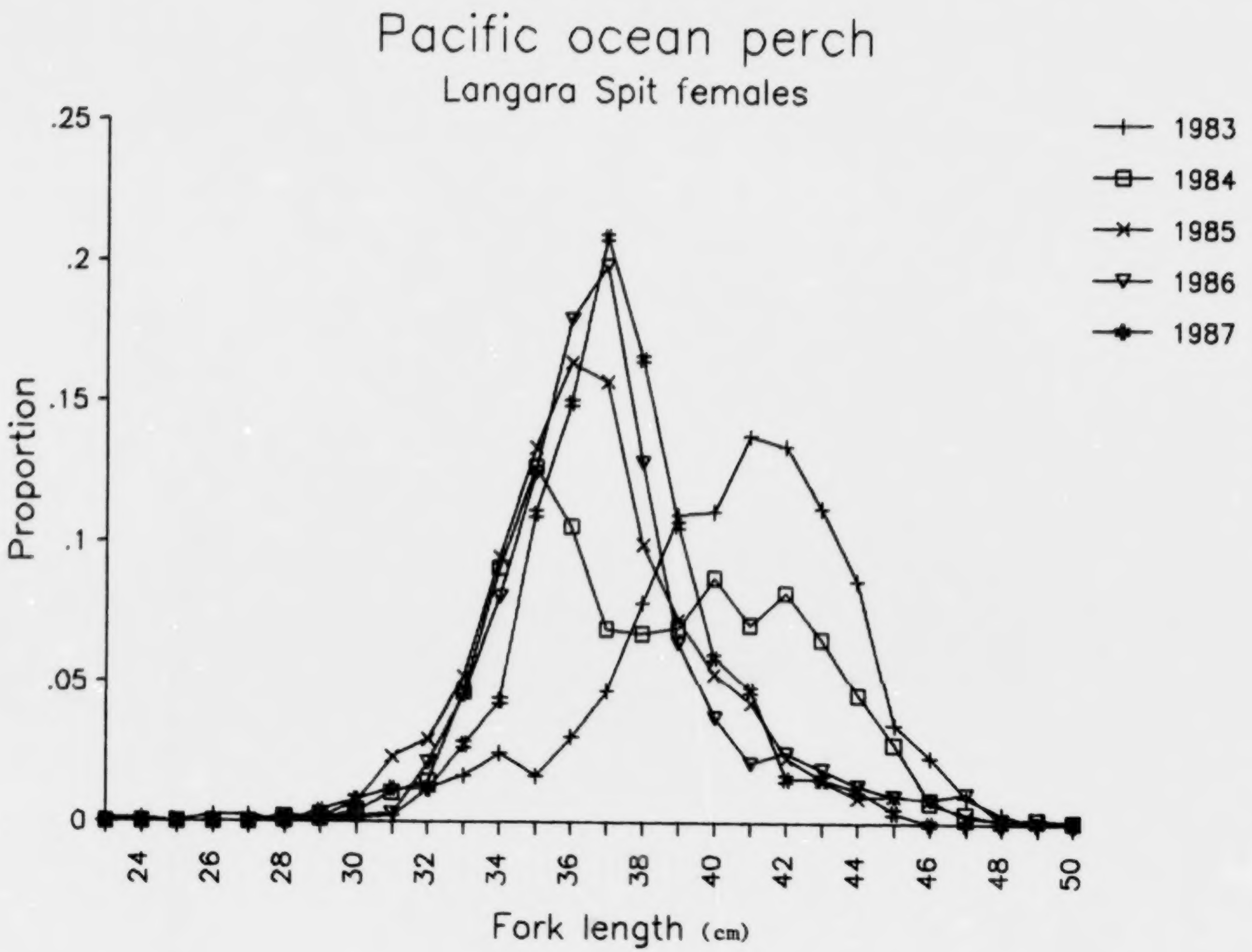

Fig. 9.21. Length frequencies of female Pacific ocean perch (S. alutus) in the Area 5E(N) (Langara Spit) fishery, 1983-1987.

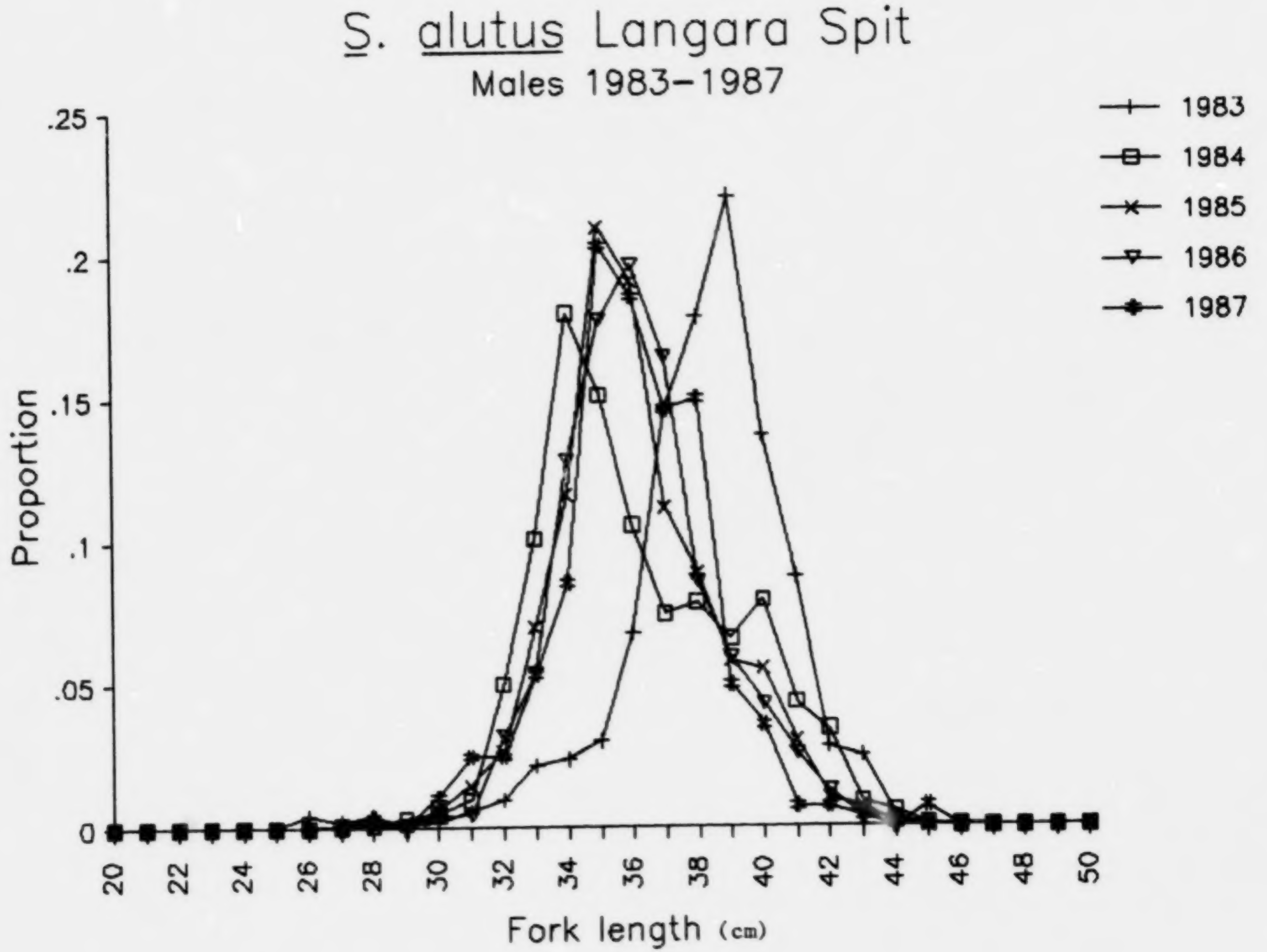

Fig. 9.22. Length frequencies of male Pacific ocean perch (*S. alutus*) in the Area 5E(N) (Langara Spit) fishery, 1983-1987.

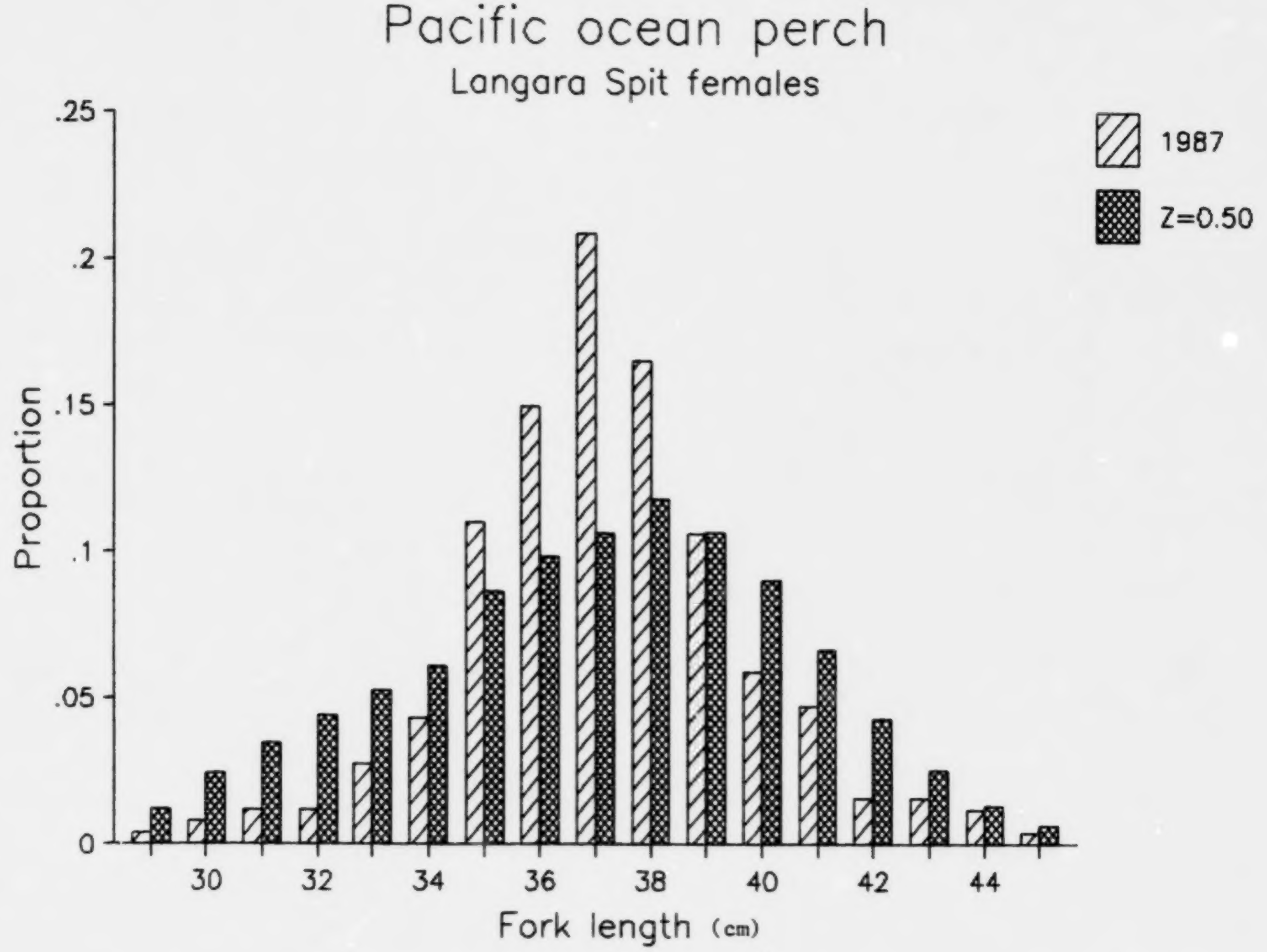

Fig. 9.23. Length frequency of female Pacific ocean perch (*S. alutus*) in the Area 5E(N) (Langara Spit) fishery in 1987, compared with a frequency generated using a known mortality rate (Z=0.25).

10.0. SHELF ROCKFISH (silvergray, yellowtail, and canary rockfish)

by R. D. Stanley

10.0.1. General Introduction

The 1985 stock assessment document (Stanley 1985) summarized the types of fishery and biological data that are available for assessment of these stocks. In addition to the accurate catch histories, which are complete back to 1967, there is baseline information on growth and longevity as well as numerous length frequency samples. A small number of these samples have been aged but there are no time series of catch-at-age information and there are few credible series of catch rates owing to a variety of reasons with the most important being the limited amount of landings associated with the annual estimates. Lacking the usual source material for analytic assessments, the starting point for discussion in previous documents has been that if there were no obvious signs of overfishing, the mean yield, over a maximum of 20 years, represented a minimum estimate of sustainable yield.

Evidence for overfishing could include declining mean size or catch rates. It also could be inferred from small size in commercial or research catches. A simulation procedure for estimating historical mortality from length frequency data was described with examples in Stanley (1985) and (1987b). The growth and fishery parameters used in the model are summarized in Tables 10.1-10.3.

The present document uses the same process of examining mean yield relative to recent catch rates and biological samples but uses this information to suggest yield ranges instead of the point yield options which characterized past documents (Table 10.4.). While the intention of these point estimates was only to provide a starting point for discussion, we feel that their use implied a stronger scientific basis and greater precision in the estimates than was the case, and thus tended to restrict managers' freedom of action.

To further emphasize the qualitative nature of most of these assessments, we have adopted the terminology of "low and high risk" to categorize the bottom and top ends of the range in place of the previous" sustainable, and non-sustainable" terminology. A guideline yield "option" of 500 t is suggested for those stocks which have no landings history such as the north coast yellowtail and canary rockfish. The suggested ranges or individual options are documented in the "Yield Options" heading in each section and summarized in Table 10.5.

Our objective in these assessments is to establish for the managers whether the mean historical yield is the minimum sustainable yield (low risk yield) and then attempt to resolve for an upper limit of what might be expected (high risk yield).

Should managers wish to increase the harvest pressure on some of the stocks, the size of the increment (increase over historical yields) should be a function of such issues as 1) the economic value of current yield, 2) current size or age composition (does it already indicate a significant impact from exploitation?), 3) current catch rates (are they already less than most rockfish stocks?) and 4) our expectation of obtaining adequate monitoring data.

The top end of the range is not to be construed as what we are confident is sustainable, rather it indicates a point, beyond which we are fairly confident it isn't sustainable. Yields equal or slightly less than the top end are to be considered high risk.

If options are chosen which turn out to be non-sustainable, we can expect to see declines in size composition and, for the larger directed fisheries, declines in catch rates. However these are imprecise indicators and cannot be consistently relied upon to identify short-term depletion. Furthermore, with limited resources we cannot maintain adequate sampling levels to monitor all stocks in all areas on a yearly basis.

Managers might therefore consider limiting the incremental yield to a maximum proportional increase of 25% in 5-year stages. The Department will then have the opportunity to assess the impact of the added removals without risking serious long-term depletion. A slightly different option could include maintaining possibly excessive harvests on some stocks for experimental purposes along the lines of the "North of 54" Pacific ocean perch fishery.

Managers are encouraged to select a yield option from within the specified range but we acknowledge that there are non-biological considerations which may lead managers to choose yield options which equal or even exceed the ranges in the absence of strong evidence of biological overfishing. We stress that the biological characteristics of rockfish, which make them poor candidates for exploitation, their poor track record in supporting significant yields, and their long recovery time once depleted be kept in mind when selecting harvest options.

10.1. Coastwide

10.1.1. Silvergray and canary rockfish

We have not considered coastwide quotas for silvergray and canary rockfish. There is no evidence for assuming they are continuous stocks over the whole coast, and managers have stated that it is their intention to manage on a stock specific basis to maximize yield.

10.1.2. Yellowtail rockfish

10.1.2.1. Introduction

The limited recoveries from a yellowtail rockfish tagging program begun in 1980 indicate widespread movement along the Canadian coast and into U.S. waters (Table 10.6). Most of the movement has been southward although this may be a result of the higher landings off Washington than B.C. in the years following the releases. In view of these returns, yellowtail rockfish is tentatively assumed to be a unit stock over its traditional central and southern fisheries. The north coast is discussed in Sections 10.5.2. and 10.6.2.

10.1.2.2. Landing statistics

The historical landings from the south and central coast areas are shown in Table 10.7 and Figures 10.1 and 10.2. The peak landings of 7512 and 4909 t resulted from midwater trawl fisheries off the west coast of Vancouver Island by Polish vessels in 1975 and Canadian vessels in 1986. Most of the remaining landings have come from bottom trawl fishing in Queen Charlotte Sound (Q.C.Sd). Mean yield 1967-1985 was 2085 t.

The estimates of catches in the offshore hake fishery are based on rockfish proportions observed in the 1983 fishery (Davenport 1985). The proportion of rockfish in the total catches was 3.9% in the National and 0.3% in the Joint-Venture fisheries of which fifty-six percent was estimated to have been yellowtail rockfish. A 1987 estimate is not provided but, assuming the same proportions, the projected hake catches of 45,000 t by joint-venture and 35,000 t by national fisheries (G. Buechler, pers. comm.) would produce catches of 800 t and 75 t respectively.

Catch rates for this stock are of little use for assessment. It is clear from Table 10.7 that no one fishery has been both significant enough in landings and of long enough duration to provide a credible time series. The major midwater landings by Canadian vessels in 1986 is without precedent, while the bottom trawl catches from Q.C.Sd have been too low in recent years to provide reliable estimates.

10.1.2.3. General biological information

Length frequency information from commercial samples is summarized in Figures 10.3 and 10.4. Each data point represents the mean length of one or more samples. The accompanying numerals indicate the quarter-year from which the samples were obtained. The horizontal lines represent the predicted mean length for theoretical populations which have been exposed to three different levels of constant total instantaneous mortality (Z) (Stanley 1987b).

While the female samples indicate a higher Z, mean size for both sexes show the same general decline in the Q.C.Sd samples from 1978 to 1986. The smaller size is also apparent in the 1985 and 1986 bottom trawl samples from the west coast of Vancouver Island. The exception to this pattern is the large mean size observed in three combined samples from the 1986 midwater fishery off Vancouver Island. Mean sizes for both sexes were equivalent to the initial sizes observed in Q.C.Sd, eight years earlier.

We have aged one sample from that 1986 fishery to examine whether those landings were the result of one particularly large recent year-class (Figure 10.5 and 10.6). The male distribution indicates a fairly broad age spectrum in contrast with the females and with other rockfish stocks known to have undergone significant exploitation (Leaman 1985). The mean size of the males (46.7 cm) implies a Z of less than 0.05 while a regression of log frequency against age indicates a value of 0.05-0.06. The 1960 year-class remains dominant in the male distribution but no incoming year-class appears responsible for the 1986 fishery.

The female distribution is highly truncated but does not reveal any dominant year-class. Regression of the female age distribution indicates a Z of 0.25. The mean length (48.1) of the females implies older fish (Z=0.10). Both the regression and length simulation approaches can err on truncated age distributions because of increased sensitivity to variability in recruitment, and error in estimating the partial recruitment factors.

10.1.2.4. Condition of the stock

While analysis of the Canadian stock is hampered by a lack of age composition and survey data, this is not the case for U.S. assessments of yellowtail rockfish. Their stock delineation uses the INPFC divisions of the "Vancouver" area, which covers Areas 3C and 3D of the B.C. coast and the northern two-thirds of the Washington coast, and the "Columbia" area which includes the remaining southern portion of Washington and the northern two-thirds of the Oregon coast. Historical landings for the two stocks are shown in Figure 10.2.

The most recent U.S. assessment (Tagart 1985) states that yellowtail stocks from both areas have been declining over the previous 19 years (1967-1985) with some stabilization over the last three years. Biomasses were estimated to be 5421-6150 t for the Vancouver area and 20,284-21,231 t in the Columbia area. The recommended catch ranges were 854-1333 t and 2227-3154 t for the Vancouver and Columbia areas respectively, with the former range being set below the equilibrium yield in order to promote stock reconstruction.

United States assessments indicate a declining biomass in recent years because of a significant decline in the relative abundance indices observed in their triennial surveys from 1977 to 1986. The original biomass estimate of 11,000 t for 1977 declined to 4976 t in 1980, to 4665 t in 1983 and, according to preliminary results (J. Tagart, pers. comm.), to 2701 t 1986. Parallelling the biomass trend, the mean size for both sexes combined has been decreasing (Fig. 10.7).

If the apparent decline is real and caused by the higher catches from 1975 to 1984, the mean annual landings over this period, 3046 and 4823 t for the Vancouver and Columbia areas respectively, represent significant overfishing over the short-term.

Canadian fish tend to be larger but the mean size in Canadian bottom trawl landings also declined 2-3 cm over the same period. Unlike the U.S. situation this response occurred during a period of limited landings. The U.S. catches may have had an impact on abundance in the Canadian zone or, the annual catches in Canadian waters of 2000-7500 t in the 1969-78 period removed many of the older (larger) fish resulting in reduced mean size in the 1981-1986 bottom trawl samples and reduced abundance as evident from the low catches during this period. Mean size may have decreased temporarily as incoming recruiting represented an increasing proportion of the stock. In obvious contradiction however, was the successful midwater fishery of late 1986 off the central coast of Vancouver Island which appeared to concentrate on older males (76% males). As mentioned earlier, a similar fishery by Polish trawlers occurred in 1975 but the fishery did not seem able to sustain itself for a second year as the Polish catch rates declined by 59% in 1976.

The mean yield of 2085 t for 1967-85 has not produced consistent signs of overfishing. An apparent reduction in availability between 1981 and 1985 as indicated by low catches, and the trend towards smaller mean size in bottom-trawl catches, conflicts with the observation of high catch rates and larger mean size in the recent midwater fishery off central Vancouver Island. The 2085 t mean yield remains a minimum estimate of sustainable yield.

While similar to other rockfishes, with respect to longevity and growth, yellowtail rockfish appear to be more mobile and, perhaps as a consequence, much more variable in availability. Yield options for this species, more than for other rockfishes, should be perceived as long-term averages. This is consistent with the management of the last few years during which regulations have not limited the harvest. When the population apparently became more available to midwater-trawl gear in late 1986, the managers allowed a large harvest in lieu of the minimal Canadian landings from 1980 to 1985.

A guideline annual yield option is still required however, as a target for mean yield. Managers may also wish to implement a ceiling annual harvest level to prevent excessive fishing during years of increased availability.

10.1.2.5. Yield options

We suggest that a yield option equal to the mean yield (2085 t) does not represent a major risk and that the yield could be increased a modest amount unless sizes and catch rates continue to decline over the short-term. The yield option must account for the expected catches of yellowtail rockfish in the 1988 offshore hake fishery.

If managers wish a yield in excess of the long-term average, the previous Polish midwater fishery and the U.S. assessments provide insight into what might be considered excessive. Polish catch rates were reduced by 50% after a one year total harvest (Polish and domestic) of 7512 t. The U.S. fisheries to the south are showing consistent signs of overfishing after only 10 years of a combined mean yield of approximately 8000 t. U.S. biologists now estimate that the maximum sustained yield of the two stocks combined lies between 1000 and 4000 t, at optimal levels.

It seems unlikely, given the Polish fishery results, the U.S. assessments, and the declining mean size in the Canadian bottom-trawl catches, that the B.C. coast could sustain more than the U.S. estimate of maximum MSY from the Washington, Oregon and southern B.C. coasts combined. A yield of 4000 t sets a upper limit to what might be expected from this stock.

With respect to the upper limit of 4000 t, an independent reviewer, as part of the Pacific Stock Assessment Review (PSARC) process, made the following comment:

"Given the following factors:

a) that the U.S. assessment indicates a declining trend in abundance over the 19 year period from 1967 to 1985;

b) that there were five consecutive extremely poor catch years in Canadian fisheries which followed eleven years with a mean yield of 3078 t; and
c) that mean length is showing a decline beginning in 1983 in Canada and slightly earlier in U.S. waters; and recognizing
d) that there seems to be a high degree of inter-annual variability in availability;

Is there reason for concern that the upper end of the yield range (from 3000-4000 t) might not be sustainable? If this is the case should the upper end be lowered or a caution to management inserted in the document?"

The low-risk option would be 1000 t, significantly below the mean yield owing to concern over declining size in bottom-trawl catches, a possibly large by-catch in the offshore hake fishery, and the possibility that the stock is continuous with the declining stock in U.S. waters. The suggested yield range is 1000-4000 t.

10.2. Strait of Georgia (Area 4B)

Catches of silvergray, yellowtail, and canary rockfish are insignificant in the Strait of Georgia.

10.3. West Coast Vancouver Island (Areas 3C+3D)

10.3.1. Silvergray rockfish--Southern Stock (Area 3C)

10.3.1.1. Landing statistics

Landings from the Canadian portion of this zone averaged 25 t from 1967-1985 and equalled 225 t in 1986 within the coastwide quota strategy (Table 10.8). Major landings have never been realized from the Canadian portion of this zone although landings did average 1000 t/yr in the U.S. portion of Area 3C between 1977 and 1979 (Figure 1.1).

10.3.1.2. General biological information

Three samples were collected during a 1985 charter. They were all however, collected in the Clayoquot Canyon area in minor area 24 (Figure 1.2) whereas over 80% of the 1986 commercial landings for this stock came from further south in minor area 23.

The samples contained relatively small fish. The size compositions were what could be expected for a Z of 0.15-0.20 for males and 0.20-0.30 for females (Table 10.9 and 10.10). Both ranges are at or beyond the upper limit of what could be considered acceptable for a species with an estimated natural mortality rate (M) of approximately 0.03-0.07 (Archibald et al. 1981).

10.3.1.3. Yield options

Given that there have never been significant landings of silvergray rockfish for over 20 years in spite of major groundfish fisheries on these grounds and the relatively small size in the available samples, it seems unlikely there is a major under-exploited resource of silvergray rockfish in this area. The sustainable yield is probably greater than the mean yield of 25 t/yr but may be less than the 225 t captured in 1986. The suggested yield range is 25-200 t.

10.3.2. Canary rockfish--Southern Stock (Area 3C)

10.3.2.1. Landing statistics

Landings in this fishery remained low in 1986 (201 t) under a coastwide quota strategy (Table 10.11). Mean yield 1967-1985 was 215 t, too low to provide usable CPUE estimates.

10.3.2.2. General biological information

We collected samples from minor Areas 23 and 24 during the 1985 and 1986 charters. In comparison with theoretical distributions, the size compositions in the 1985 samples implied Z values of approximately 0.15 for both sexes. Archibald et al. (1981) estimated natural mortality for males to be 0.05. We have never found samples of older (25+ years) females. It is not clear whether the females have a higher mortality rate or they are just not available to the fishery. The 1985 size composition was similar to a commercial sample obtained from Clayoquot Canyon in 1983. Samples from the 1986 charter were composed of smaller fish with implied Z values of 0.30.

The observation that we can still easily obtain samples with large fish, as shown in the 1985 samples, is encouraging and suggests that the fishery can probably continue to sustain the historical yield of 215 t. The 1986 charter samples indicated smaller fish, but for the present we attribute it to sampling variability. However, even using the larger 1985 male size composition, we can infer from the length frequencies that fishing has had a significant impact.

10.3.2.3. Yield options

The long-term mean yield of 215 t remains a minimum estimate of sustainable yield and can be considered the low-risk option. One is referred to the comments in Section 10.0. regarding the choice of a yield option if overfishing is not evident.

The absence of significant landings of canary rockfish for 20 years in spite of heavy groundfish exploitation on these grounds strongly suggests that there has never been a biomass capable of supporting an annual harvest of 500-600 t such as has been observed in more northern stocks. The long-term sustainable yield therefore probably lies within the range of 200-400 t.

10.3.3. Combined silvergray and canary rockfish yield option (Area 3C)

The applicability of assemblage management (Leaman and Stanley 1985) is dependent on what managers choose as the yield option for each stock. If the options are not dissimilar the managers may wish to simply add the two options. We suggest that the combined option be less than the sum of the two in case one of the species becomes especially available during the 1988 fishing year. This would be particularly important if managers choose yield options significantly in excess of mean historical yields. This principle applies to all applications of assemblage management.

10.3.4. Silvergray rockfish--northern stock (Area 3D)

10.3.4.1. Landing statistics

Landings for 1986 were 868 t from a combined coastwide quota of 4100 t for canary and silvergray rockfish (Table 10.12). Mean catch from 1967-1985 was 276 t. Including 1986, landings have averaged 676 t the last four years. Nominal catch rates were lower but qualified catch rate shows no trend in recent years.

The last two stock assessments have identified the mean catch of 200+ t as a minimum estimate of sustainable yield but recommended that managers consider a modest increment to 350 t. Catches have exceeded 350 t by almost 100% for the last four years. This was partly a result of managers choosing an assemblage quota for silvergray and canary rockfish in excess of the recommended sustainable option and partly because of disproportionate landings between rockfish species and among areas under joint and coastwide quotas.

10.3.4.2. General biological information

We conducted sampling charters in this area in 1985 and 1986. The general lack of catch-at-age data and usable catch rate estimates for shelf rockfish makes assessments for these species almost wholly reliant upon length frequency samples as indicators of stock status. Modelling exercises (Stanley 1987b) have shown that length composition can be useful for rockfish stock assessment provided it is representative. The purpose of the charters was to collect baseline length frequency data and examine the variability among samples.

The analysis of sampling variability is in progress but the size distributions have been summarized in Figures 10.8 and 10.9 and Table 10.9. The samples were similar between years with both overall samples revealing relatively small fish in comparison with the theoretical means. Examined separately, none of the minor areas indicates a Z of less than 0.15 and the overall size composition indicates a Z of 0.15-0.20 for males and 0.20-0.30 for females.

The charter observations were consistent with commercial samples collected from the Nootka ground (minor Area 25) in 1983 and 1985 but much smaller than a Kains Island (minor Area 27) sample from 1982.

We have aged two samples from the charters (Figures 10.10-10.13). These results correspond with the length data and indicate a dependence on newly recruiting fish. Samples collected from Q.C.Sd in the late 1970s indicate much older age composition to the point that age of full recruitment was estimated to be in excess of 20 years (Archibald et al. 1981: Figure 6; Stanley 1987b: Figure 1). This fishery is apparently highly dependent on partially recruited age classes.

Westrheim (1975) reported that the size at 50% maturity for this species is 43 cm for males and 45 cm for females. Although the mean size of the samples indicates a significant impact from fishing, the fishery has not shifted to juvenile fish. There would still seem to be sufficient residence time in the population for individuals to accomplish multiple spawning.

10.3.4.3. Condition of the stock

Partial recruitment parameters can vary among stocks and over time, but the aged samples from Nootka and the length frequency samples for both years for the whole area provide a consistent picture of a population which has undergone significant exploitation. The most likely explanation for the young age composition is that the traditional yield of 200+ t/yr, augmented by 4 recent years of a 600 t/yr harvest, has had a major impact on this stock.

The alternative explanation is that the older fish are still numerous but are swamped numerically in the samples by very successful recent year-classes. This requires the coincidence that the charters happened to take place 15 years following a 5-10 year period of very high recruitment, the first period of high recruitment in 50-60 years. Massive incoming recruitment should also lead to rising catch rates, however, qualified catch rates remain relatively stable and low for a rockfish fishery (0.37-0.53 t/hr). Nominal rates are declining.

10.3.4.4. Yield Options

The charter observations support the premise that the sustainable yield for this stock may not be any larger than what the stock has traditionally produced. On this basis anything significantly greater than 250 t can be considered to be a high risk quota.

Managers may wish to consider maintaining a high yield for two or more years in order to use this stock as a test bed for the management of this species. By virtue of the two charters, this stock provides us with the best set of baseline biological data with which to monitor the effects of "high-risk" yields. If 250 t is the sustainable yield for this fishery it implies a biomass in 1984, prior to the increase in harvest, of 5000 t. The 4-year harvest of 676 t/yr would then have reduced the biomass to 3400 t. A further reduction of 1000 t, by allowing yields of 750 t/yr for two years, should be obvious in the age composition by repeating the sampling charter in 1989. If at that time no changes are detected, then the sustainable yield will be assumed to be in excess of 250 t, and possibly as high as 650 t.

The suggested yield range is 250-350 t.

10.3.5. Canary rockfish--northern stock (Area 3D)

10.3.5.1. Landing statistics

Annual catches have declined from 882 t in 1984 to 727 t in 1985, and 521 t in 1986 (Table 10.13). The preliminary landings for 1987 indicate a further decline. As canary rockfish are part of a combined shelf rockfish quota strategy with silvergray rockfish, the declines were partly caused by increased catches of silvergray rockfish. Mean yield, 1967-1985 has been 500 t. Catch rate, both nominal and qualified (25%), also show a steady decline from 1984.

10.3.5.2. General biological information

We have aged one recent commercial sample from the 1985 fishery on the Nootka ground (Figures 10.14 and 10.15). The male distribution indicates a large proportion of older fish while the female distribution is almost exclusively less than 20 years old. Length composition observed during the 1985 and 1986 charters indicated a greater proportion of older fish.

10.3.5.3. Yield options

The declining catches and catch rates argue against a sustainable yield option in excess of the mean yield of 500 t. Managers may wish to consider a more conservative option. While the declining catches and more particularly, the declining catch rates are a source of concern, managers are advised that landings have varied in the past and the current trends in catch rates may be an artifact of a varying management regime.

We know of no analytic technique for identifying a high-risk option from the available information but in light of the declining catch rates and landings, yields more than 25 percent greater than the historical mean would seem excessive. The suggested harvest range is 500-600 t. Managers are advised that an independent PSARC reviewer feels that this is too liberal and proposes a yield range of 350-500 t.

10.3.6. Combined yield options--silvergray and canary rockfish (Area 3D)

The separate options for the two species determines whether assemblage management is appropriate. Landings over the last four years indicate a 50:50 split between the two species. As long as the desired yield options correspond to this ratio then a combined quota is appropriate. If managers wish to curtail landings of one of the species, a combined yield option might still be effective but may require use of specific trip limits as was employed for Moresby Gully silvergray rockfish in 1987.

10.4. Queen Charlotte Sound (Area 5A+5B)

10.4.1. Silvergray rockfish

10.4.1.1. Landing statistics

The catch of 700 t in 1986 was lower than the suggested yield option of 750 t (Table 10.14). Failure to reach the option occurred in the context of a coastwide yield option. No trends in nominal or qualified catch rate are apparent. Including estimates of Japanese catches in the 1970s (738 t), the mean yield 1967-1985 was 691 t.

10.4.1.2. General biological information

Length samples collected in 1982 indicated bi-modal age composition of young and relatively old fish. A small 1983 sample indicated only small fish. A commercial sample collected in 1986 from Cape Scott Spit was composed of very small males (Z=0.30) and a small but bimodal distribution of females.

10.4.1.3. Yield options

Although a source for concern, one recent sample of small fish is not conclusive evidence for overfishing. The mean yield remains the minimum estimate of sustainable yield. Managers may wish to increase the harvest pressure on this stock but it would seem unlikely that this resource could match Pacific ocean perch in productivity so it would be extremely surprising if it could sustain harvests in excess of 1000 t (see Section 9.5.3). The historical absence of major yields and the small size in the 1986 sample argue against a sustainable harvest much in excess of the historical yield. A suggested harvest range is 700-1000 t, although a PSARC reviewer indicated that yield should not exceed the long-term yield.

10.4.2. Canary rockfish

10.4.2.1. Landing statistics

Landings declined slightly in 1986 partly owing to high catches of silvergray rockfish within the same coastwide quota (Table 10.15). Qualified catch rates exhibit a slow but relatively steady decline from the onset of the limited Canadian fishery in 1978. The minimal landings preclude attaching any confidence to annual estimates but the trend is noteworthy. Partial landings for 1987 indicate a higher CPUE. Landings averaged 364 t from 1967-1985.

10.4.2.2. General biological information

No new biological information has been gathered since previous assessments. Two samples obtained from the Goose Island grounds in 1983 indicated relatively old males with an implied total mortality rate of 0.10. The females were much smaller (younger) with an implied Z value of greater than 0.30.

10.4.2.3. Yield options

Landings continue to decline within the constraint of a coastwide combined yield option for both species of rockfish. While it is obvious that catches in some stocks must decline if others increase within a combined option, it still implies that there is not a vast unexploited biomass when fishing pressure and success shifts so readily to other stocks. While we can assume that the mean yield of 364 t is a minimum estimate of the sustainable yield, there is no evidence to suggest that this yield can be significantly increased. The low-risk option is the long-term mean yield of 364 t. Managers may wish to increase harvest pressure a modest amount. We suggest a harvest range of 350-500 t for consideration. A PSARC reviewer suggests that yield should not exceed the long-term average.

10.4.3. Combined yield option--silvergray and canary rockfish

A combined yield option for silvergray and canary rockfish is suggested for Q.C.Sd. It can be the sum of the individual yield options if the two options chosen by managers follow the historical landings proportion of 2 to 1 silvergray to canary rockfish. Otherwise, the comments of Sections 10.3.3. and 10.3.6. apply.

10.5. Hecate Strait (Area 5C+5D)

10.5.1. Silvergray rockfish

10.5.1.1. Landing statistics

Landings from this stock, which is assumed to reside in Moresby Gully, became significant in 1977 with the advent of a Pacific ocean perch fishery in the southern part of the gully (Table 10.16). Mean catch from 1977-1985 was 396 t. The 1986 landings were 1082 t.

Table 10.17 summarizes past landings with the corresponding yield options. Landings exceeded the area quota in 1985. The overrun in 1986 occurred as part of the coastwide yield strategy. Catches in 1987 will probably be lower owing to a 9 t trip limit which was imposed July 1 for this stock. The qualified catch rate in 1986 was 1.1 t/hr, a decline of 19% from the 1985 catch rate. The preliminary estimate for 1987 equals that of 1986. The nominal rate increased slightly in 1986 but is down in 1987.

10.5.1.2. General biological information

The length and age composition observed in commercial samples from 1985 and 1986 indicate that a significant proportion of older fish still persist in the population as indicated in one 1985 sample shown in Figures 10.16 and 10.17. As this is the only shelf rockfish stock that we can monitor from the beginning of its exploitation, we are attempting to develop a catch-at-age time series for this stock. We hope to include it in the assessment analyses in subsequent years.

An area productivity study reported in the assessment document for 1987 (Stanley 1987a) indicated that an annual yield of 1000 t might be expected for this stock based on the surface area of habitat in Moresby Gully (50-150 fathoms).

10.5.1.3. Yield options

The recommended sustainable yield option was raised from 300 to 600 t in 1983, prior to any effective quota restrictions under the assumption that a significant biomass might be present. We suggested that the option be maintained at that level for 3-5 years. Based on 1985 and 1986 catch rates and stock composition, the stock is not exhibiting significant signs of overfishing. Apparently, the fishery since 1977, with a mean yield of 396 t, has not yet had a significant impact. A yield option of 400 t can now be considered a minimum estimate of the sustainable. Managers may wish to maintain the current option of 600 t or even increase it for another trial period. The area productivity study would suggest that a yield of more than 1000 t is not likely. The suggested harvest range is 400-1000 t.

10.5.2. Yellowtail rockfish

Yellowtail rockfish landings continue to be minor in Hecate Strait with 96 t landed in 1986. Significant landings (150-600 t) last occurred during the pollock fishery in Dixon Entrance between 1976 and 1979. There are no analytical means for identifying yield options, managers may wish to consider a ceiling yield option as they chose for the 1987 fishing year.

10.5.3. Canary rockfish

Canary rockfish catches from Hecate Strait continue to be low as only 63 t were landed in 1986. Managers may wish to choose a ceiling yield option as they have in the past.

10.6. West Coast of Queen Charlotte Islands (Area 5E)

10.6.1. Silvergray rockfish

10.6.1.1. Landing statistics

The silvergray rockfish fisheries on the west coast of the Queen Charlotte Islands remain incidental to the Pacific Ocean perch and yellowmouth rockfish fisheries (Table 10.18). The southern fishery has averaged 109 t of landings since the advent of the rockfish fishery in this area (1977-1985). One commercial sample was obtained in 1983 from Rennell Sound which indicated young fish with an implied Z of 0.15-0.25.

The northern fishery was inconsequential until 1984, the first full year of the open fishery for Pacific ocean perch. Landings reached approximately 250 t the first two years then declined to 172 t in 1986. It appears that they will be lower in 1987. Both nominal and qualified catch rates also appear to be falling. It is too still too early to make any conclusions, but this fishery is beginning to show signs of not being able to support any significant removals.

Managers may wish to continue to allow open fishing on this stock. Restrictions would necessitate dumping as long as there is open fishing for Pacific ocean perch. It also provides for an experiment in parallel with the one for Pacific ocean perch.

10.6.1.2. Yield options

No analytic assessments are possible for these two stocks. Suggested ranges are 100-250 t for the southern stock and 100-150 for the northern stock with the suggestion that no constraints be placed on the latter fishery until conclusion of the experimental fishery for Pacific ocean perch.

10.6.2. Yellowtail and canary rockfish

The fishery for these two species off the west coast of the Queen Charlotte Islands remains insignificant. No yellowtail landings and only 110 t of canary rockfish were reported to have come from these grounds in 1986. Managers may wish to continue with guideline quotas as in past years.

Table 10.1. Growth and partial recruitment factors used for predicting mean length for silvergray rockfish under different mortality rates (Area 3C, 3D, and 5A) (Archibald et al. 1981; Shaw et al. 1981).

Growth parameters	Males	Females
L_∞	57.0	60.6
k	0.088	0.068
t_0	-4.13	-8.46
σ_1 - standard deviation of mean length about predicted mean length	0.26	0.26
σ_2 - standard deviation of individual length about mean length	2.67	3.00
Partial Recruitment Factors[a]		
Age (yr)		
8	0.00	0.00
9	0.02	0.01
10	0.02	0.01
11	0.03	0.02
12	0.03	0.03
13	0.05	0.04
14	0.07	0.05
15	0.09	0.08
16	0.13	0.10
17	0.16	0.14
18	0.22	0.18
19	0.29	0.22
20	0.43	0.29
21	0.62	0.35
22	0.85	0.40
23	1.00	0.49
24	1.00	0.56
25	1.00	0.64
26	1.00	0.75
27	1.00	0.86
28	1.00	0.94
29-88	1.00	1.00

[a] Partial recruitment factors derived as in Stanley (1987b) from unpublished data.

Table 10.2. Growth and partial recruitment factors used for predicting mean length for yellowtail rockfish under different mortality rates (Archibald et al. 1981; Shaw and Archibald 1981).

Growth parameters	Males	Females
L_∞	48.5	52.3
k	0.153	0.157
t_0	-2.37	-0.95
σ_1 - standard deviation of mean length about predicted mean length	0.586	0.600
σ_2 - standard deviation of individual length about mean length.	1.87	2.74
Partial Recruitment Factors[a]		
Age (yr)		
5	0.04	0.05
6	0.14	0.11
7	0.32	0.21
8	0.54	0.36
9	0.72	0.56
10	0.92	0.81
11	1.00	0.98
12	1.00	1.00
13-85	1.00	1.00

[a] Partial recruitment factors derived as in Stanley (1987b) from unpublished data.

Table 10.3. Growth and partial recruitment factors used for predicting mean length for canary rockfish under different mortality rates (Areas 3C + 3D + 5A + 5B) (Archibald et al. 1981; Shaw and Archibald 1981).

Growth parameters		Males	Females
L_∞		54.1	55.3
k		0.114	0.209
t_0		-3.98	2.00
σ_1	- standard deviation of mean length about predicted mean length	1.00	1.00
σ_2	- standard deviation of individual length about mean length	3.00	3.00
Partial Recruitment Factors[a]			
	Age (yr)		
	7	0.00	0.00
	8	0.01	0.01
	9	0.08	0.08
	10	0.16	0.16
	11	0.25	0.25
	12	0.36	0.36
	13	0.52	0.52
	14	0.78	0.78
	15	0.95	0.95
	16-86	1.00	1.00

[a] From data presented by Golden and Demory (1984) for Oregon samples.

Table 10.4. The recommended (1986-1988) sustainable yield options in comparison with landings (t) for 1986 and 1987.

Area	Rockfish species	1986		1987[a]		1988
		Yield option	Landings	Yield option	Landings	Yield ranges
3C	Silvergray	100	225	100	94	25-200
	Canary	200	201	200	93	200-400
3C+D	Yellowtail	250	3825	b	1038	1000-4000[cd]
3D	Silvergray	350	868	350	170	200-350
	Canary	550	521	550	183	500-600[d]
5A+B	Silvergray	750	700	750	469	700-1000[d]
	Yellowtail	1500	1084	b	988	c
	Canary	500	262	500	256	350-500[d]
5C+D	Silvergray	600	1082	600	449	400-1000

[a] To July 10, 1987.
[b] Recommended coastwide quota, 1500 t.
[c] For Areas 3C+3D+5A+5B.
[d] Yield ranges considered too high by PSARC reviewer.

Table 10.5. Mean yield (1967-1985), 1986 landings, signs of overfishing, and suggested yield ranges for shelf rockfish.

				Signs of overfishing[a]				Suggested
Area	Rockfish species	Mean yield (t)	1986 Landings (t)	Small size	Declining mean size	Catches	Catch rate	yield range (t)
3C	silvergray	25	225	Y[b]	u	increasing	u	25-200
	canary	215	201	Y	Y[c]	stable	u	200-400
3D	silvergray	276	868	Y	u	increasing	decreasing[d]	200-350
	canary	500	521	N	u	decreasing	decreasing	500-600
5A+5B	silvergray	691	700	u	u	decreasing[e]	stable	700-1000
	canary	364	262	u	u	decreasing	decreasing	350-500
5C+5D	silvergray	396	1082	N	u	stable	stable	400-1000
	yellowtail	minor	96	(-------------- u ----------------------)				(500)
	canary	minor	63	(-------------- u ----------------------)				(500)
5E-S	silvergray	109[f]	295	(-------------- u ----------------------)				(500)
5E-N	silvergray	65[f]	172	u	u	decreasing	decreasing	50-150
5E	yellowtail	minor	0	(-------------- u ----------------------)				(500)
	canary	minor	110	(-------------- u ----------------------)				(500)
3C+3D+5A+5B								
	yellowtail	2085	4909	Y[g]	Y[g]	increasing	u	1000-4000

[a] symbols: Y=yes, N=No, S=stable, U=unknown
[b] biological samples from Clayoquot Canyon area
[c] smaller but probably because of sampling variability
[d] declining nominal catch rates
[e] probably because of catches in other areas
[f] 1977-1985
[g] only in Queen Charlotte Sound bottom trawl samples.

Table 10.6. Summary of yellowtail rockfish movements from tag recoveries to July 1, 1987.

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1. 4622 tags were released in Q. C. Sound in 1980 and 1981. 5 have been recovered (0.11%). Of these:

    1 - didn't move (<10 km);
    1 - travelled 70 km to the northwest, going from the "Southeast Edge" to "Northwest Corner" of the Goose Island Bank;
    2 - travelled 15-20 km to the south, going from "Southeast Edge" of Goose Island Bank to Cape Scott Spit;
    1 - travelled south >300 km, going from Southeast Edge of Goose Island Bank to the Big Bank area off the Southwest coast of Vancouver Island.

2. 9417 tags were released off the southwest coast of Vancouver Island in 1980 and 1981. 24 have been recovered with locality information, 1 without (0.26%). Of these:

    12 - didn't move (≤ 10 km);
    5 - travelled south a short distance (x = 23 km), to the northern coast of Washington State;
    5 - travelled south to the south coast of Washington State (x = 140 km);
    1 - travelled east (23 km) into the Strait of Juan de Fuca;
    1 - travelled south to southern Oregon (> 500 km).

Table 10.7. South and central coast landings (t) of yellowtail rockfish, 1967-87. Catch rates (t/hr) in brackets (BT = bottom trawl; MWT = midwater trawl).

	W.C. Vancouver Island						Q.C. Sound				Total
	CAN. BT	CAN. BT (CPUE)[b]	CAN. MWT	U.S. BT	POLISH MWT	Offshore[a] Hake Fishery	CAN. BT	CAN. BT (CPUE)[b]	U.S. BT	CAN. MWT	
1967	3		-	103	-	-	19		996		1121
1968	0		-	23	-	-	23		278		324
1969	22		-	243	-	-	88		2174		2527
1970	10		-	154	-	-	176	(.52)	2629		2969
1971	12		-	128	-	-	227	(.30)	1955		2322
1972	11		-	76	-	-	692	(.53)	2735	3	3517
1973	20		-	23	-	-	516	(.53)	2753	5	3317
1974	17		-	117	-	-	150	(.35)	809	14	1107
1975	6		-	89	6700	-	317	(.32)	303	97	7512
1976	55		-	72	2339	-	611	(.30)	363	38	3478
1977	68		177	300	-	-	763	(.25)	1242	251	2801
1978	51		0	169	-	120	1462	(.51)	397	214	2413
1979	41		6	132	-	187	1314	(.68)	192	23	1895
1980	46		6	45	-	142	474	(.35)	81	0	794
1981	36		0	10	-	120	287	(.33)	-	0	453
1982	116		1	-	-	320	296	(.29)	-	13	746
1983	21		9	-	-	347	330	(.45)	-	15	722
1984	38		0	-	-	350	180	(.24)	-	18	586
1985	329	(.83)	38	-	-	264	372	(.45)	-	0	1003
1986	939	(.94)	2292	-	-	594	1082	(.48)	-	2	4909
1987[c]	493	(.70)	464	-	-	?	999	(.45)	-	99	-

[a] Catches estimated from species composition and catch rates of 1983.

[b] 25% qualification.

[c] To July 10, 1987.

Table 10.8. Area 3C landings (t), effort (h), and LPUE (t/h) of silvergray rockfish 1967-87 from Canadian and U.S. portions.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	USA	48	47	3127	.02	-	-	-
1968	USA	28	28	1547	.02	-	-	-
1969	USA	6	6	1475	.00	-	-	-
1970	CAN	2	2	119	.02	1	1	1.00
	USA	21	19	1807	.01	-	-	-
1971	CAN	2	2	2	1.00	2	2	1.00
	USA	57	53	1184	.04	-	-	-
1972	USA	7	7	1278	.01	-	-	-
1973	USA	1	1	1006	.00	-	-	-
1974	USA	9	8	817	.01	-	-	-
1975	CAN	1	1	35	.03	0	0	-
	USA	38	38	904	.04	-	-	-
1976	CAN	5	5	9	.55	0	0	-
	USA	80	80	2395	.03	-	-	-
1977	CAN	18	18	476	.04	8	5	1.60
	USA	983	983	4390	.22	-	-	-
1978	CAN	1	1	48	.02	0	0	-
	USA	958	958	5319	.18	-	-	-
1979	CAN	1	1	22	.05	0	0	-
	USA	1005	1005	3606	.28	-	-	-
1980	CAN	3	3	20	.10	2	7	.29
	USA	384	384	2514	.15	-	-	-
1981	USA	148	148	5024	.03	-	-	-
1982	CAN	3	3	224	.01	0	0	-
	USA	60	60	11819	.01	-	-	-
1983	CAN	84	84	156	.54	60	92	.65
1984	CAN	108	50	563	.09	19	67	.28
1985	CAN	110	65	296	.22	52	105	.49
1986	CAN	225	168	390	.43	118	124	.95
1987[d]	CAN	94	93	237	.39	75	105	.71

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.9. Mean size (cm) of silvergray rockfish from 1985 and 1986 charters, by sex and minor area.

Minor area	Example localities	1985		1986	
		Male	Female	Male	Female
24	Clayoquot/ Big Bank	50.7	51.4	-	-
25	Nootka/Esperanza	50.7	51.8	51.1	52.2
26	Ououkinsh	50.8	50.7	49.6	50.9
27	Kains Is.	49.0	50.4	51.5	53.7
11	Topknot	-	-	49.3	52.0

Table 10.10. Mean size of silvergray rockfish from theoretical samples corresponding to Z values of 0.05, 0.15, 0.30 for Areas 3C, 3D, and 5A.

	Mean size (cm)	
Z	Males	Females
0.05	53.8	56.6
0.15	51.0	53.6
0.30	47.1	49.7

Table 10.11. Area 3C landings (t), effort (h), and LPUE (t/h) of canary rockfish 1967-87.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	USA	226	223	3127	.07	-	-	-
1968	USA	402	400	1547	.21	0	0	-
1969	USA	154	149	1475	.10	-	-	-
1970	USA	241	225	1807	.09	-	-	-
1971	CAN	51	51	454	.11	40	199	.20
	USA	471	437	1184	.29	-	-	-
1972	USA	101	99	1278	.08	-	-	-
1973	USA	50	47	1006	.05	-	-	-
1974	CAN	10	10	391	.02	1	6	.18
	USA	29	27	817	.04	-		
1975	CAN	7	7	178	.04	2	2	.90
	USA	205	205	904	.23	-	-	-
1976	CAN	55	55	655	.08	20	66	.30
	USA	208	208	2395	.09	-	-	-
1977	CAN	100	100	1684	.06	19	80	.24
	USA	136	136	4390	.03	-	-	-
1978	CAN	14	14	254	.06	2	9	.22
	USA	202	202	5319	.04	-	-	-
1979	CAN	22	22	477	.05	4	22	.18
	USA	64	64	3606	.02	-	-	-
1980	CAN	18	18	750	.02	9	72	.12
	USA	262	262	2514	.10	-	-	-
1981	CAN	13	13	663	.02	1	7	.14
	USA	188	188	5024	.04	-	-	-
1982	CAN	101	101	1138	.09	78	96	.81
	USA	133	133	11819	.01	-	-	-
1983	CAN	146	146	505	.29	140	214	.65
1984	CAN	307	254	889	.29	241	322	.75
1985	CAN	176	123	762	.16	111	172	.65
1986	CAN	201	127	574	.22	71	101	.71
1987[d]	CAN	93	93	287	.32	74	104	.72

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.12. Area 3D landings (t), effort (h), and LPUE (t/h) of silvergray rockfish, 1967-87.

Year	Nat.	Total Landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	USA	148	148	1344	.11	-	-	-
1968	USA	177	172	1381	.12	-	-	-
1969	USA	328	328	2172	.14	-	-	-
1970	USA	350	339	2978	.11	-	-	-
1971	CAN	3	3	46	.07	-	-	-
	USA	154	154	1825	.08	-	-	-
1972	USA	435	435	1691	.26	-	-	-
1973	USA	226	226	1613	.14	-	-	-
1974	CAN	1	1	12	.08	-	-	-
	USA	227	227	1849	.12	-	-	-
1975	CAN	3	3	9	.33	-	-	-
	USA	75	75	2034	.04	-	-	-
1976	USA	246	246	1550	.16	-	-	-
1977	CAN	10	10	40	.25	9	23	.39
	USA	52	52	1037	.05	-	-	-
1978	CAN	21	21	236	.09	1	8	.13
	USA	14	14	925	.02	-	-	-
1979	CAN	21	21	109	.19	13	18	.72
	USA	243	243	1206	.20	-	-	-
1980	CAN	20	20	194	.10	7	8	.88
	USA	380	380	1334	.28	-	-	-
1981	CAN	15	15	77	.19	9	24	.38
	USA	136	136	400	.34	-	-	-
1982	CAN	126	126	164	.77	124	126	.99
1983	CAN	562	562	1299	.30	330	745	.44
1984	CAN	462	285	1081	.26	218	591	.37
1985	CAN	811	284	946	.30	221	416	.53
1986	CAN	868	522	2745	.19	356	782	.46
1987[d]	CAN	170	112	776	.14	42	103	.41

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.13. Area 3D landings (t), effort (h), and LPUE (t/h) of canary rockfish 1967-87.

Year	Nat.	Total landings[a]	Interviewed			Interviewed (25% qual.)		
			Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	4	4	41	.10	1	8	.12
	USA	352	352	1344	.26	-	-	-
1968	CAN	19	19	157	.12	10	12	.83
	USA	536	502	1381	.36	-	-	-
1969	CAN	46	46	266	.17	42	127	.33
	USA	625	597	2172	.27	-	-	-
1970	CAN	18	18	96	.19	17	89	.19
	USA	749	713	2978	.24	-	-	-
1971	CAN	15	15	79	.19	12	36	.33
	USA	540	525	1825	.29	-	-	-
1972	USA	193	193	1691	.11	-	-	-
1973	USA	443	443	1613	.27	-	-	-
1974	CAN	16	16	70	.23	14	20	.70
	USA	578	578	1849	.31	-	-	-
1975	CAN	7	7	8	.88	7	8	.88
	USA	453	453	2034	.22	-	-	-
1976	CAN	138	138	167	.83	137	141	.97
	USA	187	187	1550	.12	-	-	-
1977	CAN	96	96	124	.77	90	67	1.34
	USA	222	222	1037	.21	-	-	-
1978	CAN	54	54	180	.30	38	47	.81
	USA	861	861	925	.93	-	-	-
1979	CAN	100	92	203	.45	90	153	.59
	USA	251	251	1206	.21	-	-	-
1980	CAN	108	108	308	.35	100	132	.76
	USA	215	215	1334	.16	-	-	-
1981	CAN	53	53	266	.20	41	77	.53
	USA	61	61	400	.15	-	-	-
1982	CAN	215	215	277	.78	208	213	.98
1983	CAN	707	501	1218	.41	453	835	.54
1984	CAN	882	693	1190	.58	675	848	.80
1985	CAN	727	488	1135	.43	446	607	.74
1986	CAN	521	402	2267	.18	273	547	.50
1987[d]	CAN	183	124	763	.16	70	168	.42

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.14. Area 5A and 5B landings (t), effort (h), and LPUE (t/h) of silvergray rockfish, 1967-87.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	63	89	539	.17	63	200	.32
	USA	397	396	9,431	.04	-	-	-
1968	CAN	78	78	644	.12	37	109	.34
	USA	933	822	8,488	.10	-	-	-
1969	CAN	78	78	1188	.07	28	152	.18
	USA	1,291	1276	13,557	.09	-	-	-
1970	CAN	14	14	287	.05	6	29	.21
	USA	189	189	9,264	.02	-	-	-
1971	CAN	16	16	331	.05	6	66	.09
	USA	521	512	7,137	.07	-	-	-
1972	CAN	54	54	654	.08	21	108	.19
	USA	251	251	9,224	.03	-	-	-
1973	CAN	40	40	328	.12	33	70	.47
	USA	189	189	9,625	.02	-	-	-
1974	CAN	45	45	412	.11	9	12	.75
	USA	377	377	8,797	.04	-	-	-
1975	CAN	31	31	479	.06	19	61	.31
	USA	306	306	5,179	.06	-	-	-
1976	CAN	172	172	1,914	.09	82	224	.37
	USA	443	443	4,620	.10	-	-	-
1977	CAN	198	198	2,462	.08	123	320	.38
	USA	440	440	5,165	.09	-	-	-
1978	CAN	723	723	4,049	.18	468	1,069	.44
	USA	57	57	909	.06	-	-	-
1979	CAN	629	629	3,885	.16	429	1,225	.35
	USA	298	298	1,696	.18	-	-	-
1980	CAN	631	631	3,279	.19	495	1,538	.32
	USA	147	147	1,146	.13	-	-	-
1981	CAN	569	569	23,471	.24	462	860	.54
1982	CAN	756	735	4,558	.16	521	1,327	.39
1983	CAN	642	537	3,573	.15	365	1,100	.33
1984	CAN	922	678	3,402	.20	605	1,896	.32
1985	CAN	905	632	3,102	.20	536	1,540	.35
1986	CAN	700	564	3,812	.15	389	1,314	.30
1987[d]	CAN	469	431	2,589	.17	262	715	.37

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.15. Area 5A and 5B landings (t), effort (h), and LPUE (t/h) of canary rockfish, 1967-87.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	LPUE	Landings	Effort	LPUE
1967	CAN	41	41	535	.08	13	32	.41
	USA	216	215	9,431	.02	-	-	-
1968	CAN	49	49	576	.09	31	78	.40
	USA	1,034	937	8,488	.11	-	-	-
1969	CAN	67	67	733	.09	37	110	.34
	USA	464	418	13,557	.03	-	-	-
1970	CAN	6	6	80	.08	4	12	.33
	USA	220	220	9,264	.02	-	-	-
1971	CAN	18	18	329	.05	6	8	.75
	USA	207	183	7,137	.03	-	-	-
1972	USA	61	61	9,224	.01	-	-	-
1973	CAN	29	29	119	.24	23	80	.29
	USA	298	298	9,625	.03	-	-	-
1974	CAN	3	3	81	.04	1	7	.14
	USA	257	257	8,797	.03	-	-	-
1975	CAN	23	23	403	.06	15	17	.88
	USA	189	189	5,179	.04	-	-	-
1976	CAN	92	92	1,558	.06	16	49	.33
	USA	447	447	4,620	.10	-	-	-
1977	CAN	121	121	2,356	.05	53	192	.28
	USA	288	288	5,165	.06	-	-	-
1978	CAN	263	263	2,692	.10	101	242	.42
	USA	8	8	909	.01	-	-	-
1979	CAN	308	308	3,070	.10	211	582	.36
	USA	62	62	1,696	.04	-	-	-
1980	CAN	281	281	2,199	.13	198	451	.44
	USA	88	88	1,146	.08	-	-	-
1981	CAN	185	185	1778	.10	86	206	.42
1982	CAN	359	331	3,223	.10	210	706	.30
1983	CAN	360	315	2,939	.11	163	466	.35
1984	CAN	498	312	2,474	.13	225	678	.33
1985	CAN	369	260	2,507	.10	154	529	.29
1986	CAN	262	211	2,931	.07	64	253	.25
1987[d]	CAN	256	247	1,735	.14	131	269	.49

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To July 10, 1987.

Table 10.16. Area 5C and 5D landings (t), effort (h), and LPUE (t/h) of silvergray rockfish, 1971-87.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings	Landings	Effort	LPUE	Landings	Effort	LPUE
1971	CAN	34	34	229	.15	24	121	.20
1972	CAN	61	61	232	.26	44	54	.81
1973	CAN	10	10	147	.07	-	-	-
1974	CAN	13	13	64	.20	11	34	.33
1975	CAN	11	11	191	.06	4	5	.79
1976	CAN	121	121	1,429	.08	55	414	.13
1977	CAN	234	234	2,059	.11	142	468	.30
1978	CAN	232	232	1392	.17	177	301	.59
1979	CAN	380	375	2,881	.13	189	473	.40
1980	CAN	337	337	1,886	.18	235	381	.62
1981	CAN	304	263	1,610	.16	221	258	.86
1982	CAN	121	100	1,339	.08	59	94	.63
1983	CAN	333	288	883	.33	247	310	.80
1984	CAN	597	332	1,050	.32	283	545	.52
1985	CAN	1,023	708	1,268	.56	577	429	1.35
1986	CAN	1,082	1,056	1,796	.59	1,024	927	1.10
1987[a]	CAN	449	401	1,048	.38	362	314	1.15

[a] To July 10, 1987.

Table 10.17. Area 5C and 5D landings (t) and recommended quotas for silvergray rockfish, 1979-85.

Year	Total landings	Recommended sustainable yield	Quota	Fishery closed when quota was reached
79	380	-		
80	337	300		
81	304	300		
82	121	400		
83	333	600[a]	300	no
84	540	600[a]	600	no
85	1023	600	600	yes
86	1082	600	Coastwide	Trip limit imposed
87[b]	449	600	600	Trip limit imposed

[a] Area 5C only.
[b] To July 10, 1987.

Table 10.18. Area 5E-N and 5E-S landings (t), effort (h), and LPUE (t/h) of silvergray rockfish, 1977-87.

Year		Total landings	Interviewed			Interviewed (25% qual.)		
			Landings	Effort	LPUE	Landings	Effort	LPUE
1977	S	20	20	136	.15	0	0	-
	N	0	0	0	-	0	0	-
1978	S	124	124	572	.22	56	105	.53
	N	16	16	91	.18	16	21	.76
1979	S	44	44	189	.23	30	19	1.58
	N	8	8	95	.08	0	0	-
1980	S	104	104	246	.42	81	97	0.84
	N	15	15	17	.91	15	17	.91
1981	S	57	22	74	.30	12	12	1.00
	N	2	2	10	.20	0	0	-
1982	S	27	22	152	.14	7	4	1.75
	N	38	30	56	.54	27	9	3.00
1983	S	130	130	414	.31	44	58	.76
	N	16	11	108	.10	1	1	1.00
1984	S	78	71	246	.29	47	104	.45
	N	248	233	731	.32	61	33	1.88
1985	S	212	175	466	.38	85	142	.60
	N	245	245	1258	.20	158	219	.72
1986	S	295	245	601	.41	112	154	.73
	N	172	170	1772	.10	35	39	.89
1987[a]	S	93	83	563	.15	14	36	.40
	N	68	68	925	.07	6	20	.31

[a] To July 10, 1987.

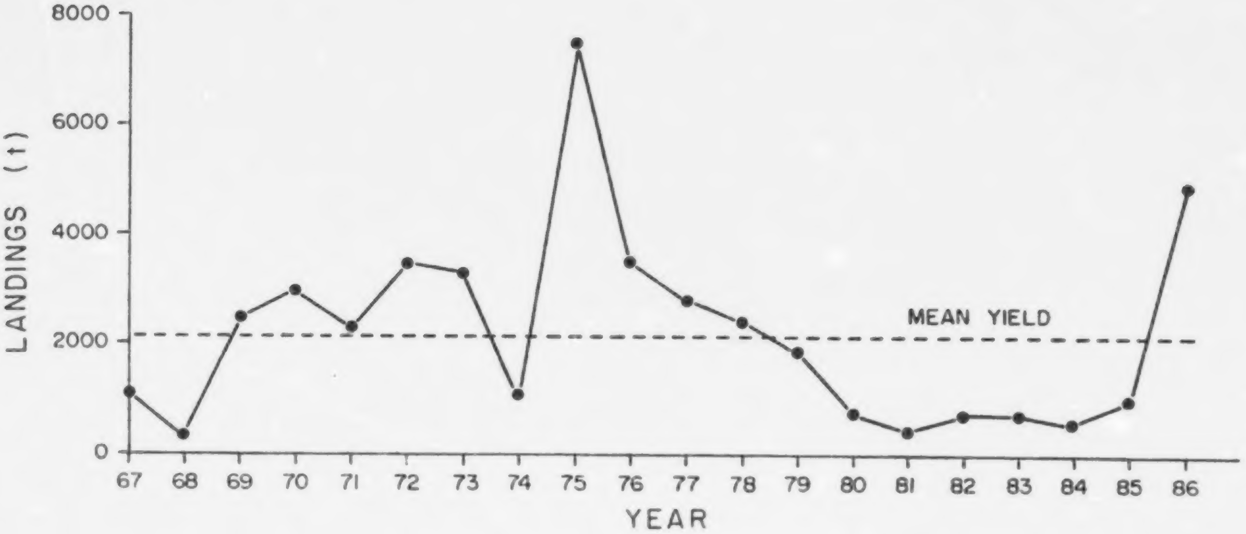

Fig.10.1. Mean landings of yellowtail rockfish from the southern and central B.C. coast.

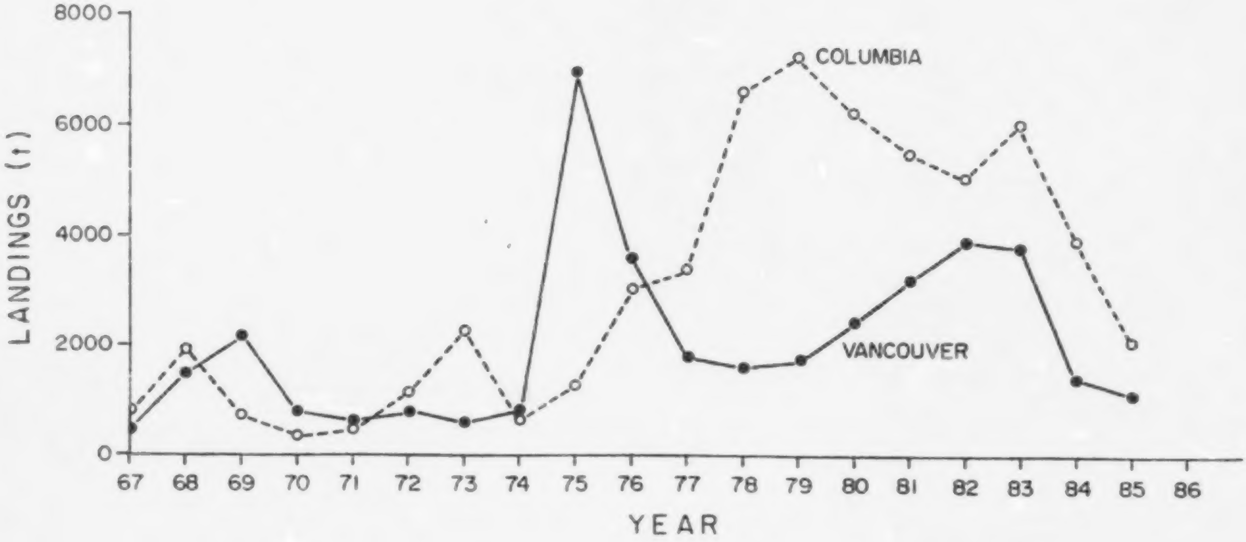

Fig. 10.2. Mean landings of yellowtail rockfish from Columbia and Vancouver INPFC zones.

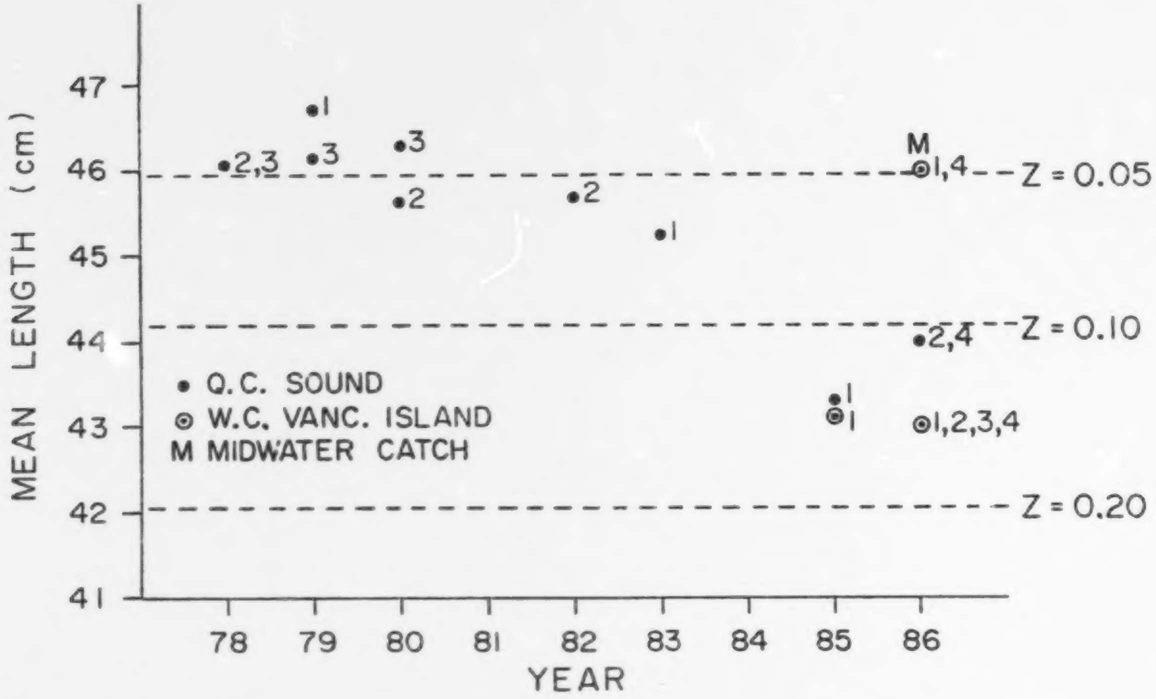

Fig. 10.3. Mean length for male yellowtail rockfish from commercial samples.

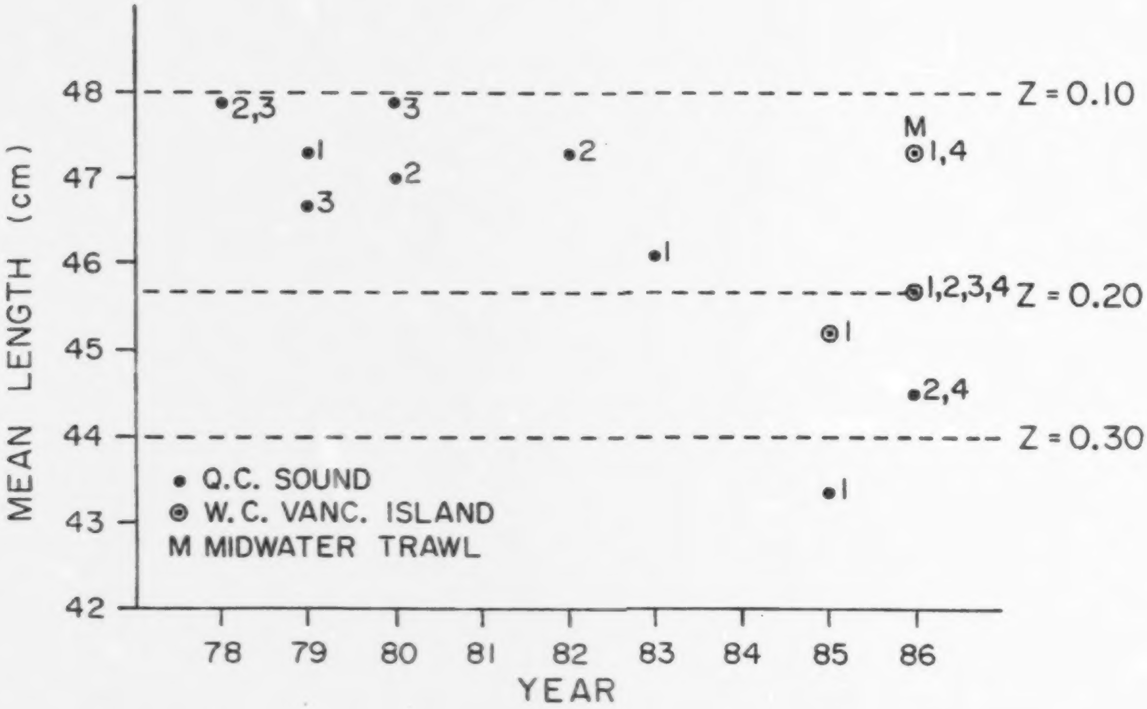

Fig. 10.4. Mean length for female yellowtail rockfish from commercial samples.

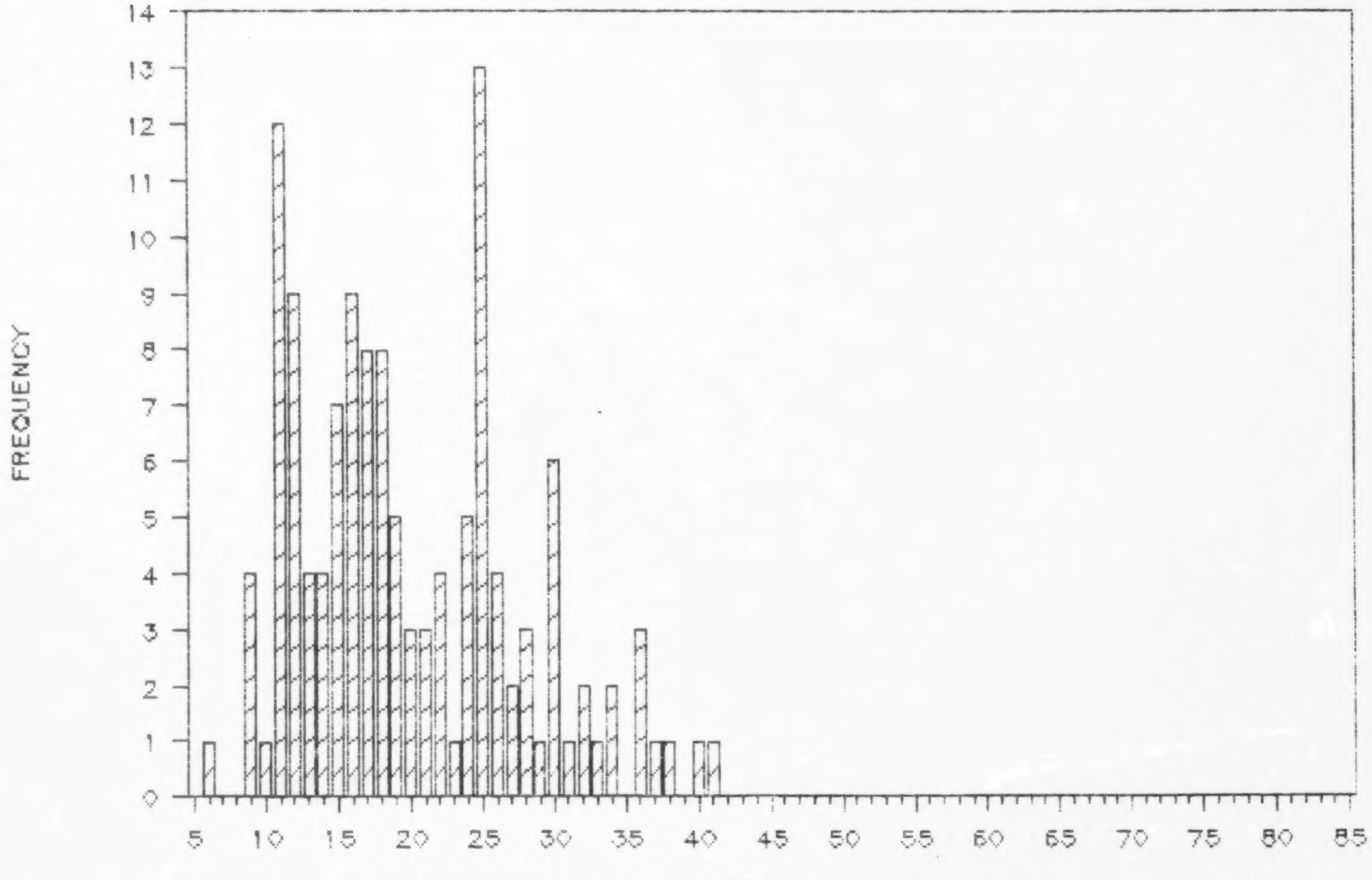

Fig.10.5. Age composition of male yellowtail rockfish from 1986 commercial midwater trawl fishery off Nootka.

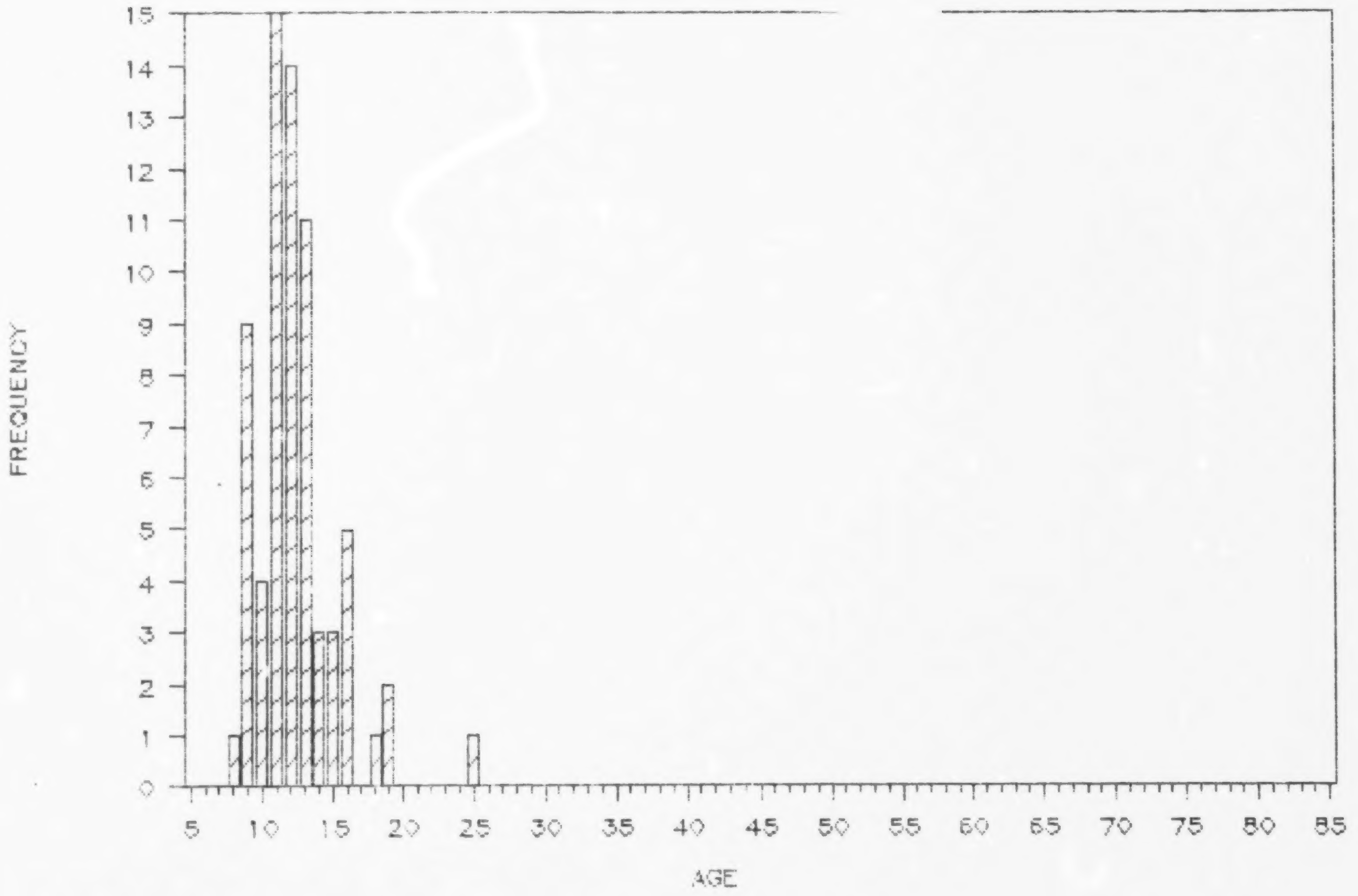

Fig. 10.6. Age composition of female yellowtail rockfish from 1986 commercial midwater trawl fishing off Nootka.

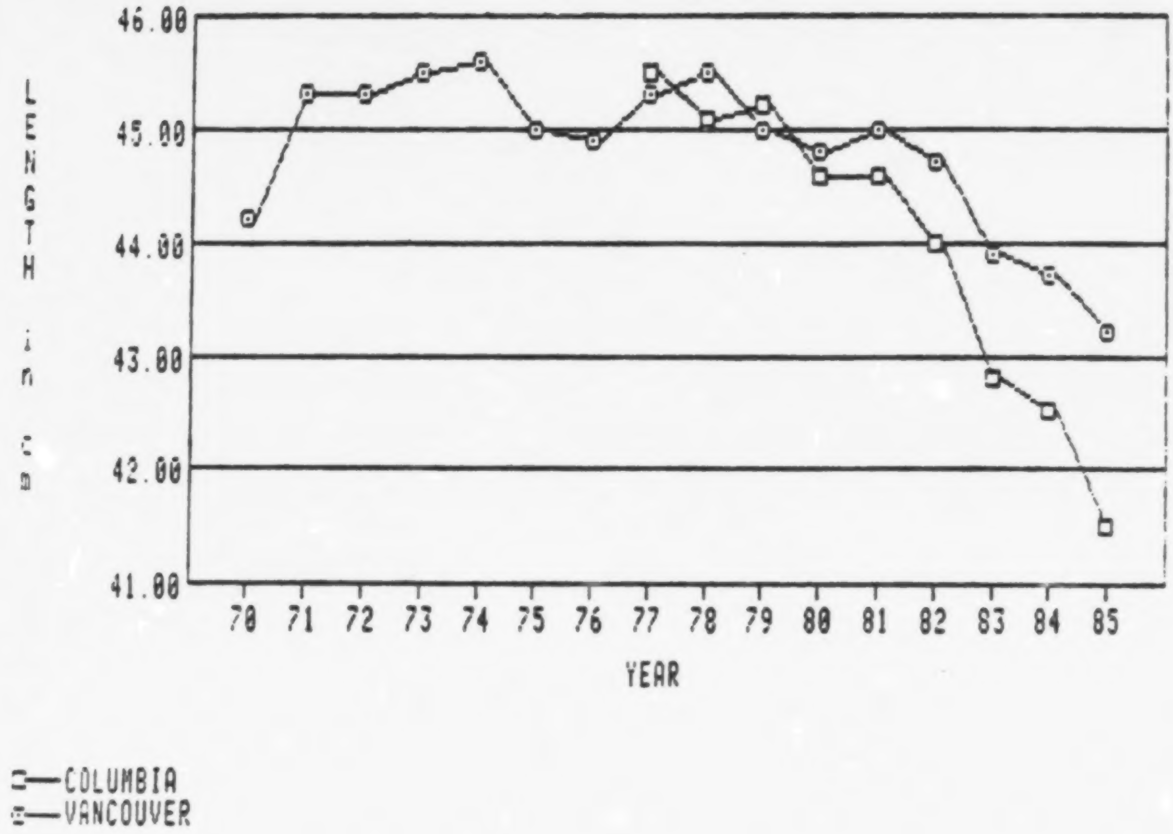

Fig. 10.7. Three year moving average of yellowtail rockfish mean length in the INPFC Vancouver and Columbia areas (Tagart 1985).

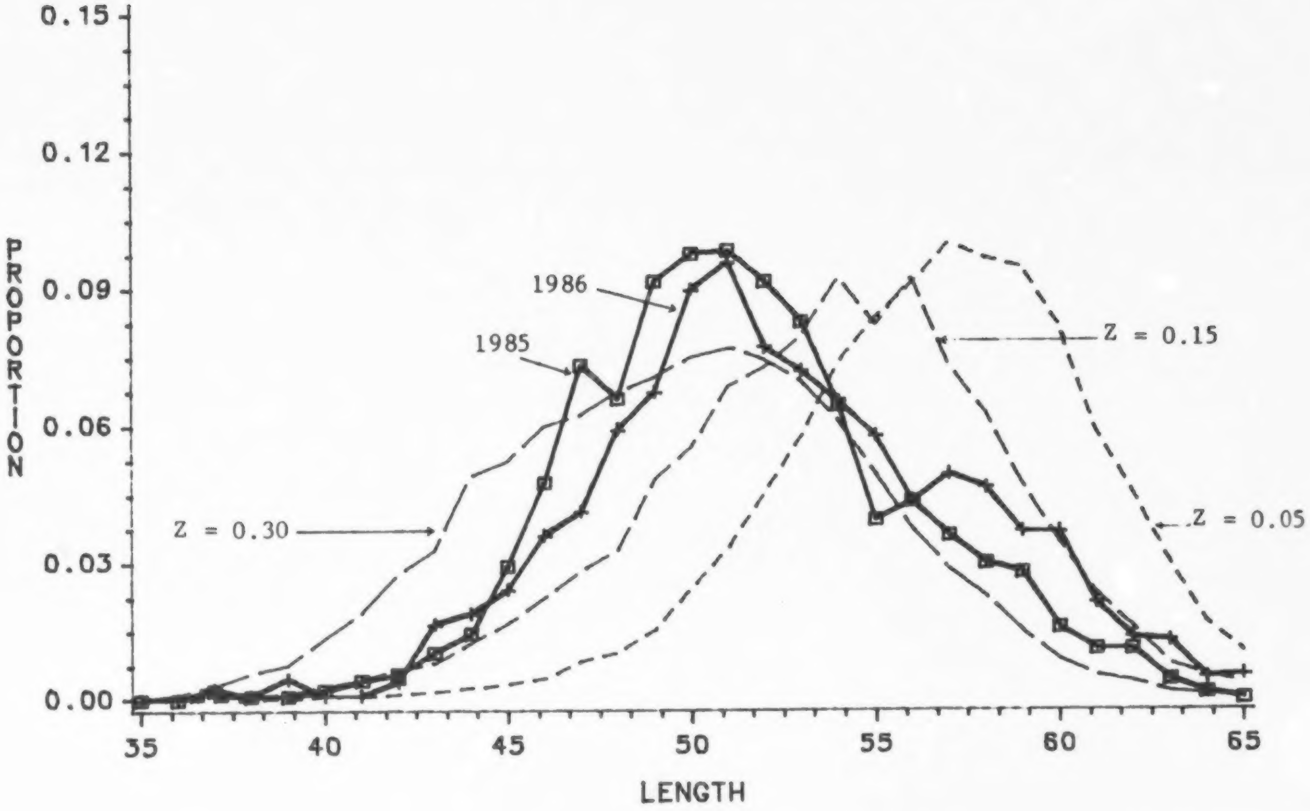

Fig. 10.8. Sample and theoretical length distribution of female silvergray rockfish from Area 3D.

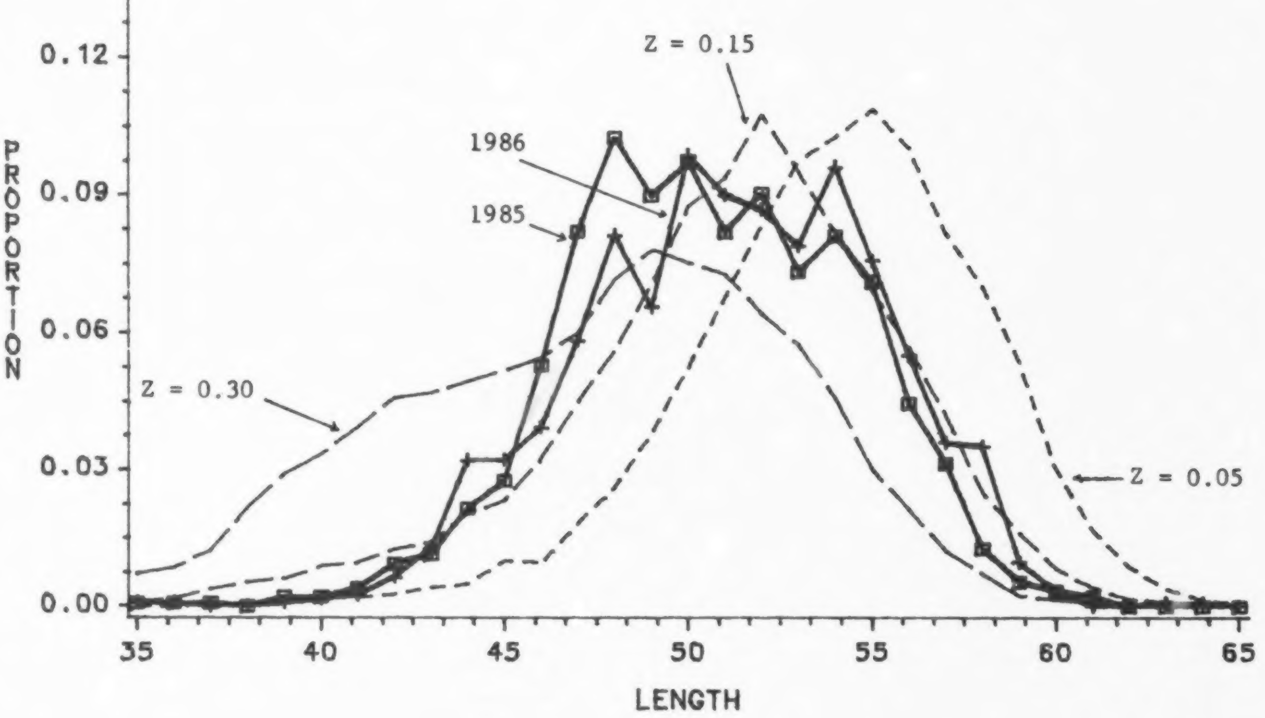

Fig. 10.9. Sample and theoretical length distributions of male silvergray rockfish from Area 3D.

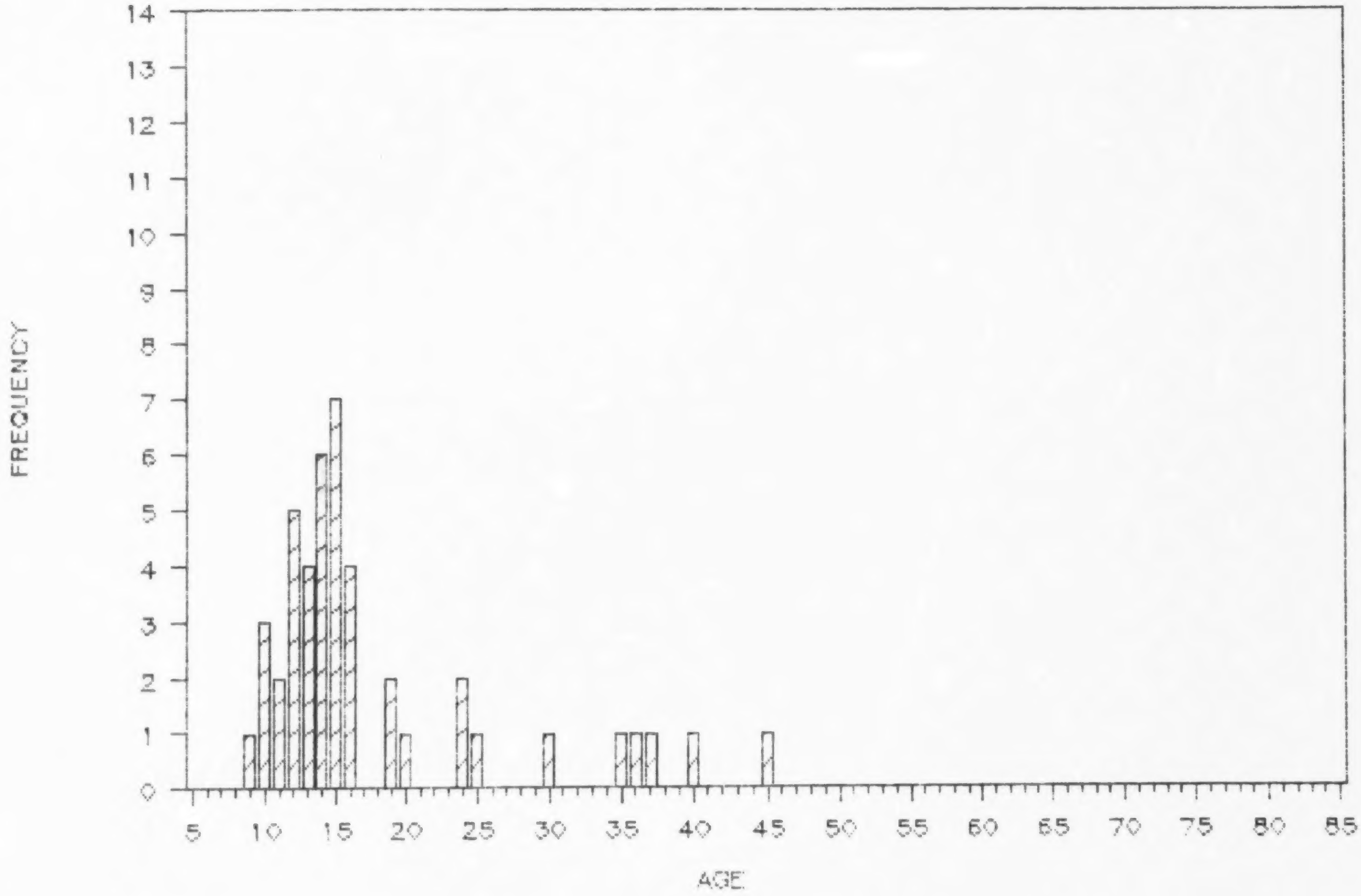

Fig. 10.10. Age composition of female silvergray rockfish from 1985 Nootka charter sample.

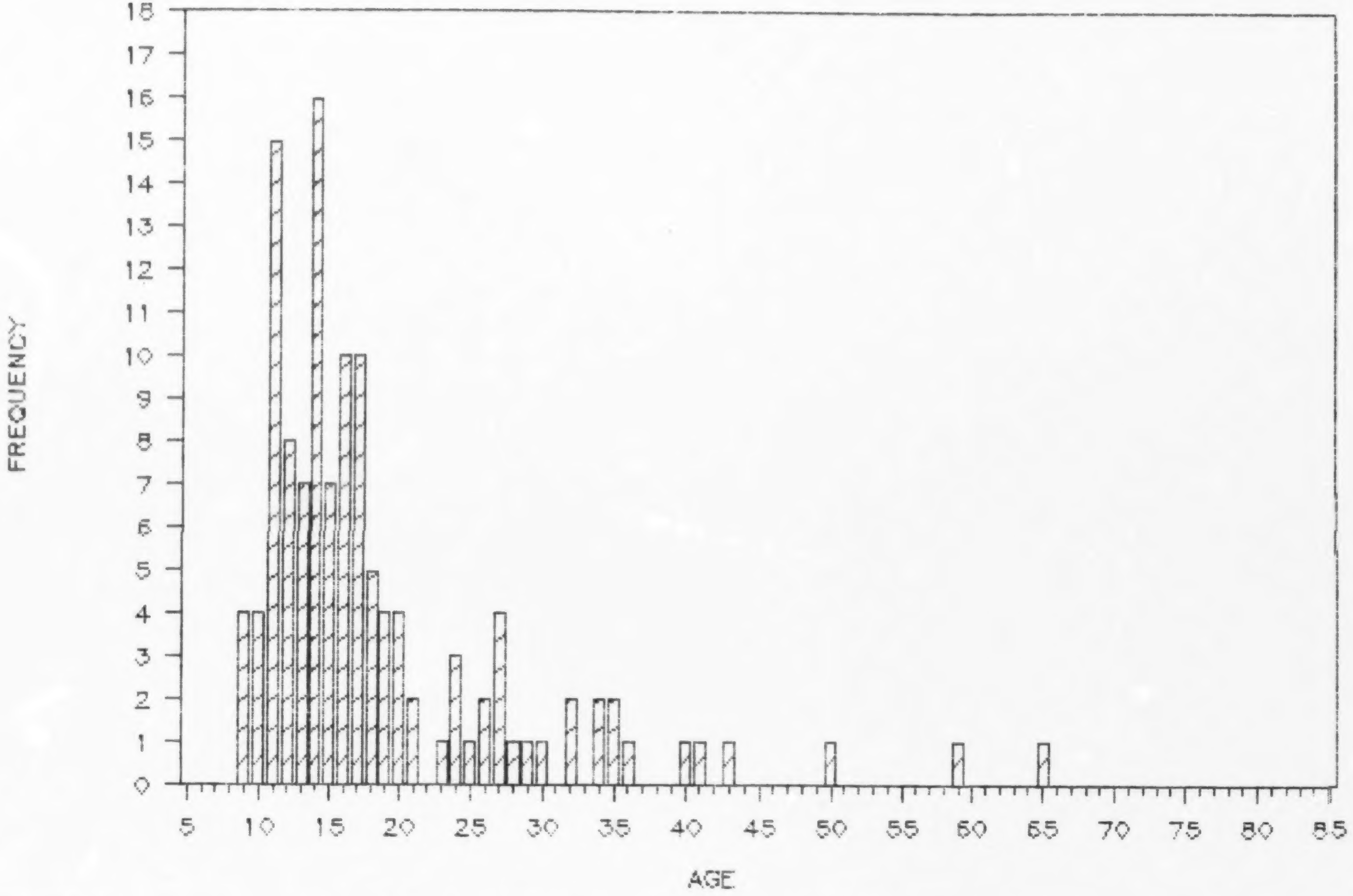

Fig. 10.11. Age composition of female silvergray rockfish from 1986 Nootka charter sample.

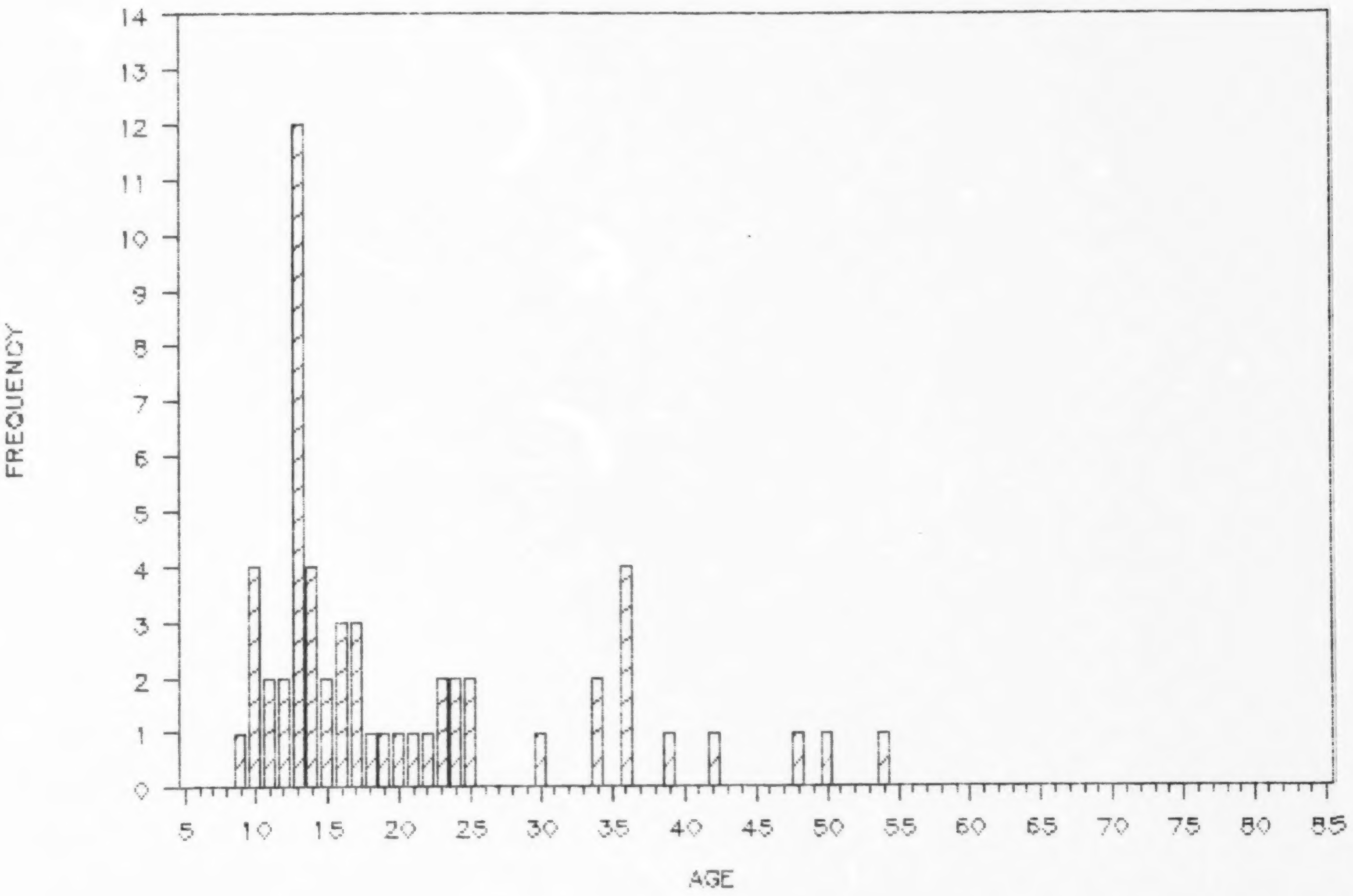

Fig. 10.12. Age composition of male silvergray rockfish from 1985 Nootka charter sample.

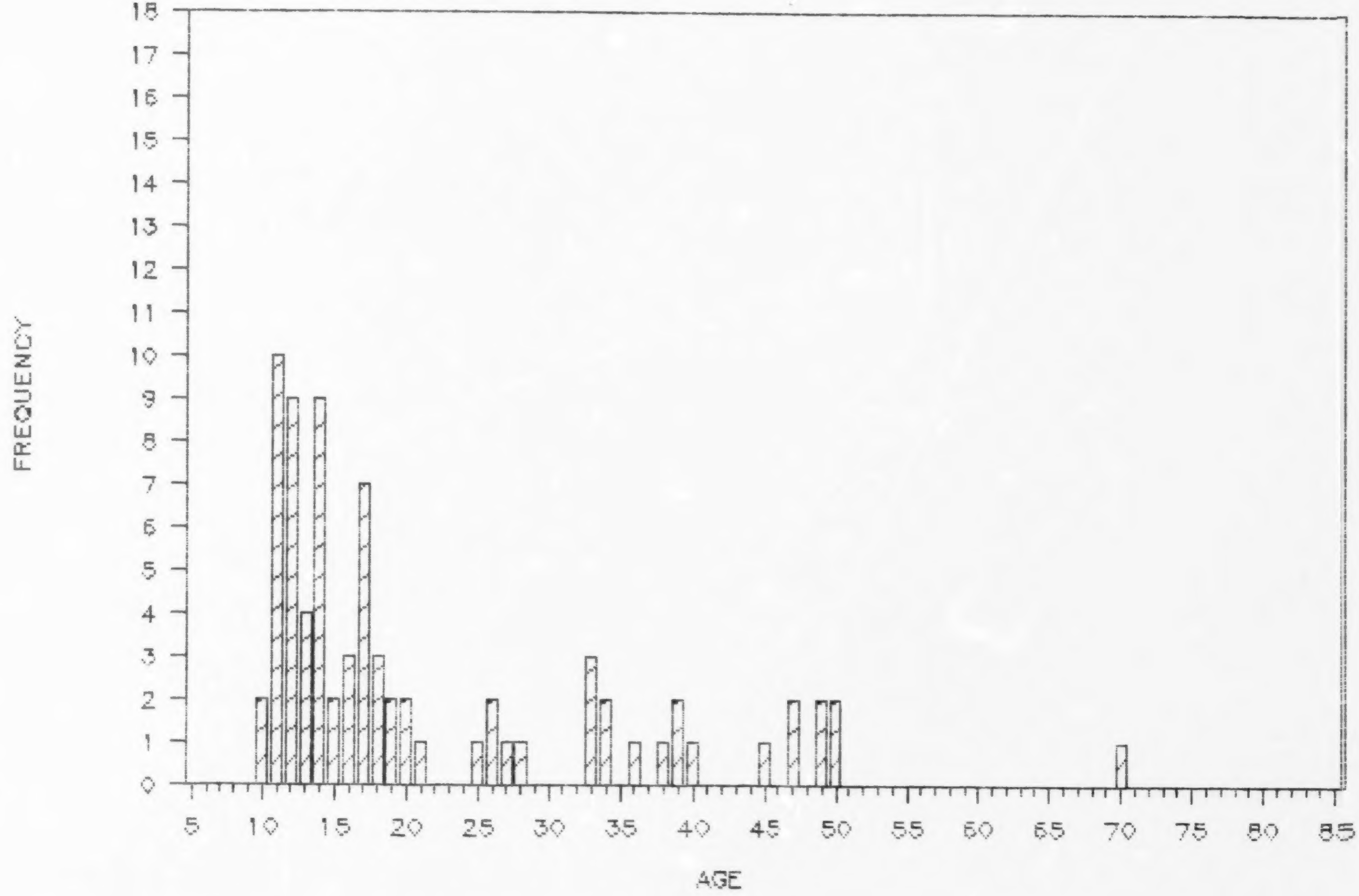

Fig. 10.13. Age compositions of male silvergray rockfish from 1986 Nootka charter sample.

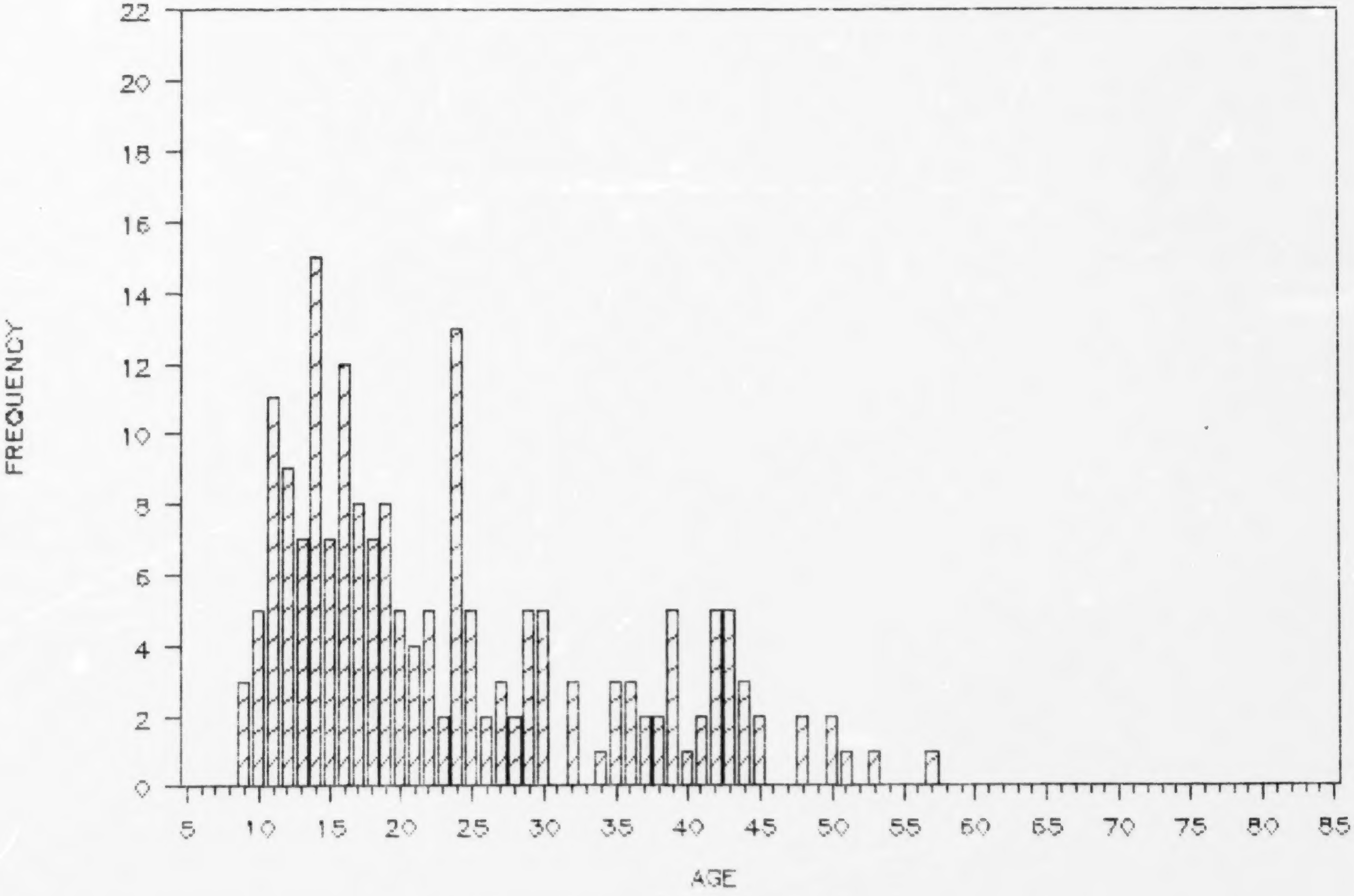

Fig.10.14. Age composition of male canary rockfish from 1985 Nootka commercial sample.

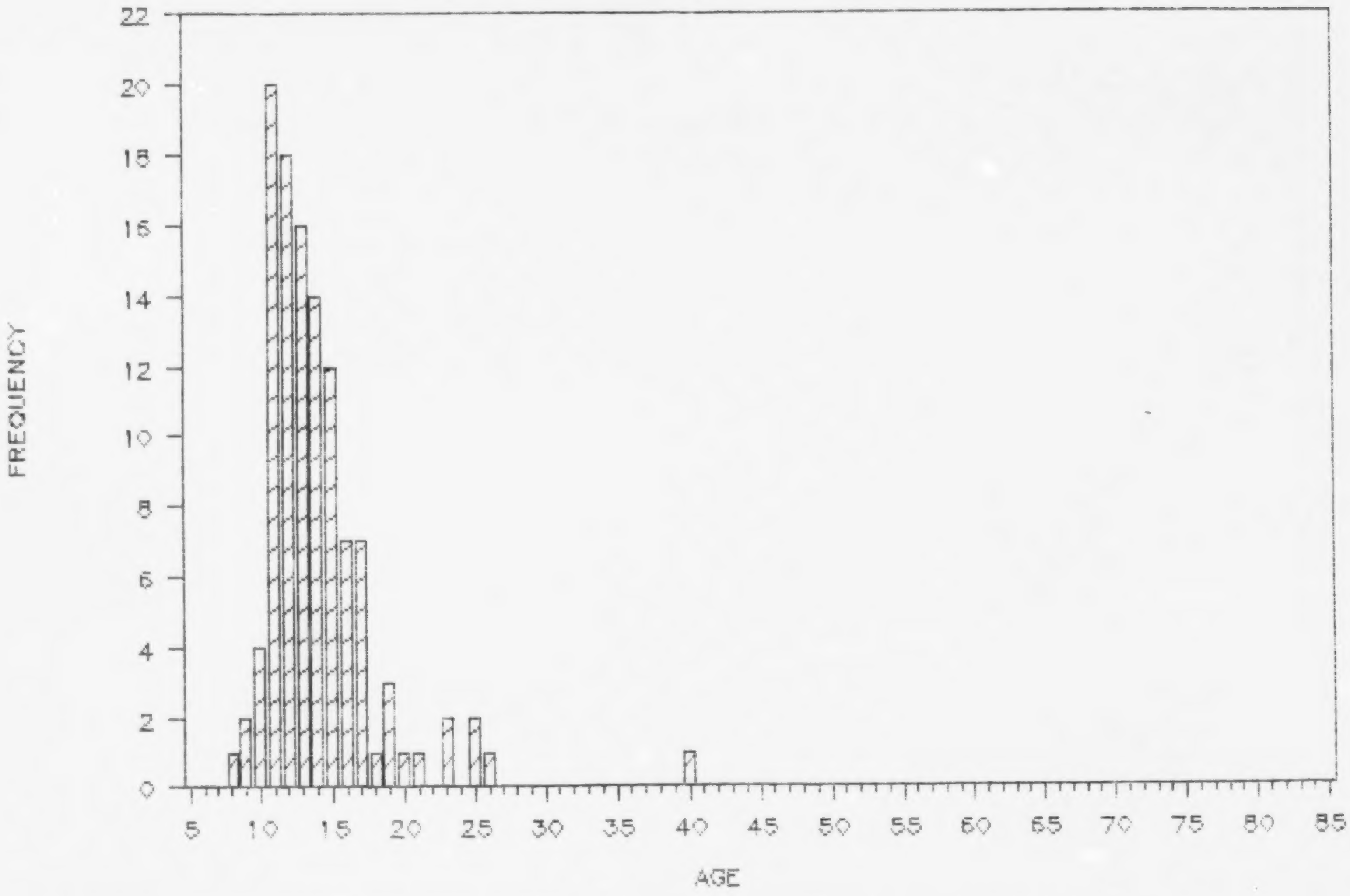

Fig. 10.15. Age composition of female canary rockfish from 1985 Nootka commercial sample.

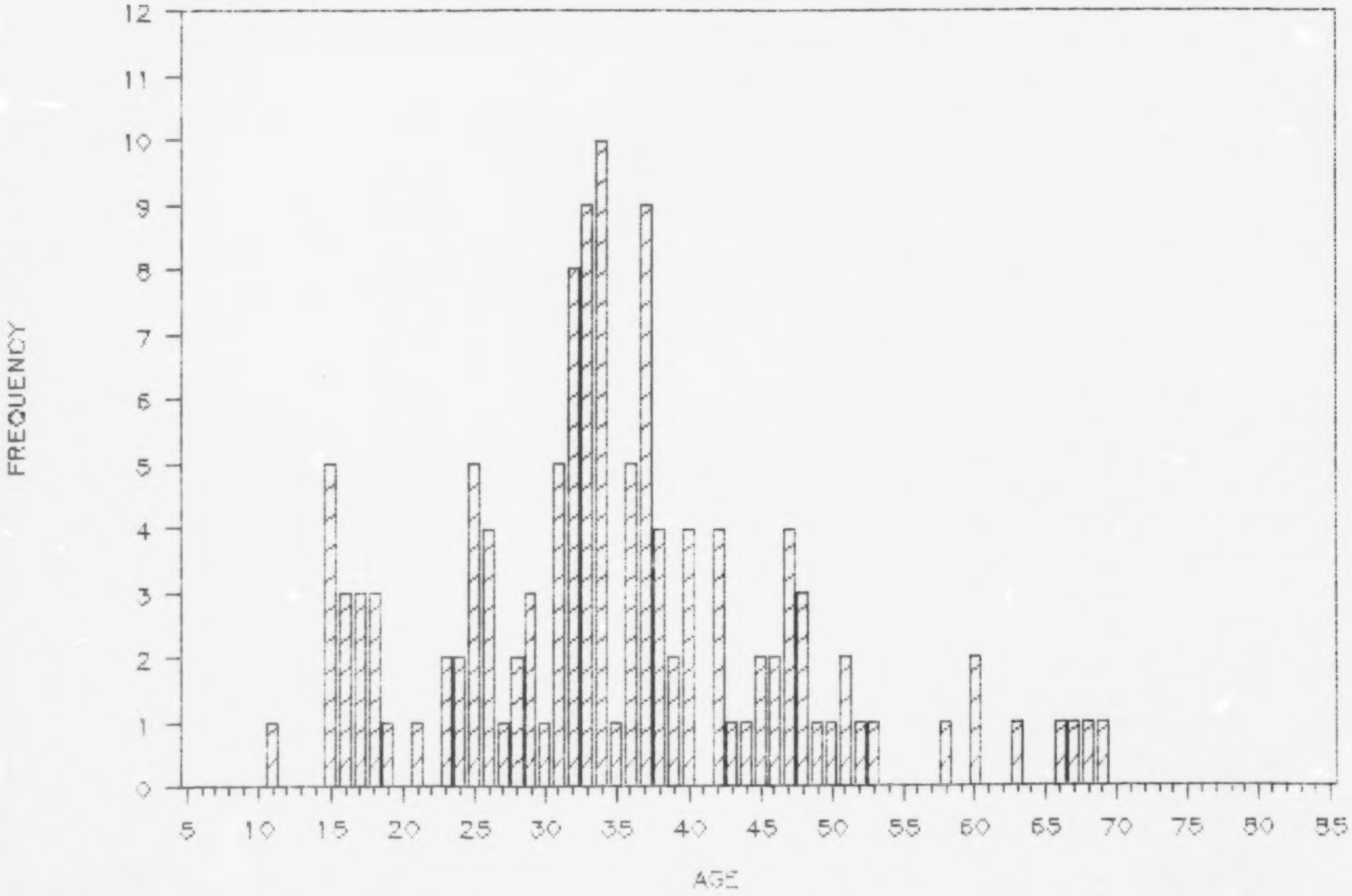

Fig. 10.16. Age composition of male silvergray rockfish from a 1985 commercial sample from Moresby Gully.

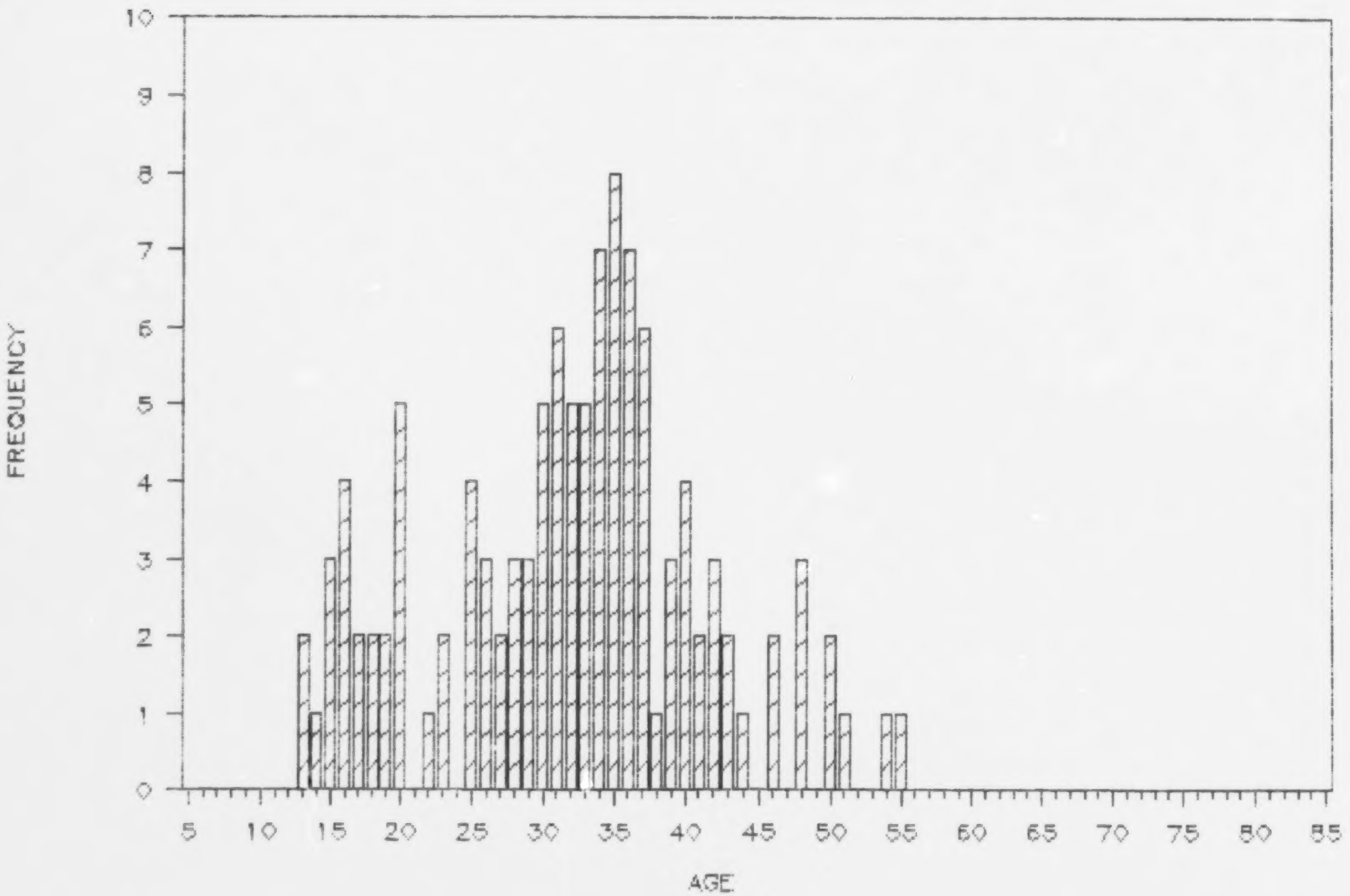

Fig. 10.17. Age composition of female silvergray rockfish from a 1985 commercial sample from Moresby Gully.

11.0 INSHORE ROCKFISH

by L. J. Richards

11.1 Coastwide.

Yield options are not proposed on a coastwide basis.

11.2 Strait of Georgia

11.2.1 The fishery

The inshore rockfish fishery occurs predominantly in the Strait of Georgia and adjacent inside waters of Vancouver Island (Fig 1.2). Most of the commercial vessels use handline/troll or longline gear. The commercial fishery in its present form began to expand about 1977 (Fig. 11.1). At that time a market developed for live rockfish to supply restaurants and retail outlets, primarily in Vancouver's Chinatown. Rockfish are also exploited by the sport fishery.

There had been no restrictions on landings by the commercial fishery prior to 1987. In 1987, a winter closure for Area 4B was implemented between Jan. 1 and Apr. 15. The closure was designed to reduce overall levels of effort. The timing of the closure coincided with a lingcod closure and covered the major period of parturition. In addition, an experimental quota of 75 t was placed on area 12. The sport catch of rockfish has been limited coastwide by a bag limit of eight fish per day since 1986.

In 1984 a program was initiated to obtain biological samples of the commercial handline landings (Cass et al. 1986). Based on the 13 samples collected between 1984-86, quillback rockfish (Sebastes maliger) is the dominant species and accounts for 86% (by number) of the landings. Copper rockfish (S. caurinus) accounts for 14% and there are minor landings (<1%) of several other species including yellowtail rockfish (S. flavidus), tiger rockfish (S. nigrocinctus), yelloweye rockfish (S. ruberrimus) and kelp greenling (Hexagrammos decagrammus). In contrast, quillback rockfish, copper rockfish and yelloweye rockfish account for 54%, 23% and 15%, respectively, of the rockfish landings by the sport fishery, based on the 1985 creel census (T. Shardlow and T. Hoyt, unpublished data).

11.2.2 Landing statistics

Most of the trawl landings of rockfish have historically been from Areas 18, 19, and 20 (Table 11.1). There were also significant trawl landings (over 10 t) in the 1950s and 1960s in Area 14 and in the late 1960s and early 1970s in Area 17. Annual trawl landings of rockfish averaged 98 t between 1954-70. Since 1970 however, annual trawl landings have decreased to an average of 42 t. In general, trawl landings of rockfish have been incidental to other fisheries, especially the Pacific cod fishery, although a yellowtail rockfish fishery has existed in Area 20. The large trawl landing from area 20 in 1986 was predominately yellowtail rockfish and bocaccio (S. paucispinis).

Handline/troll and longline landings have been combined for the analysis. Vessels may use both gear types and these two types are confounded in the sales slip files. Line landings of rockfish were historically less than trawl landings, and averaged 65 t annually between 1954-76 (Table 11.2). Since 1976, landings have increased reaching 475 t in 1986. Area 13 has been the most important area in recent years. Landings in Area 13 increased dramatically in 1982, peaked at 198 t in 1984, and then decreased to 141 t in 1986. Coincident with the decrease in landings in Area 13, there was an increase in landings in Areas 12, 17, and 19. Area 12 landings jumped from 33 t in 1984 to 136 t in 1986.

Sport landings of rockfish as estimated by the Strait of Georgia creel survey, averaged 172,000 pieces annually between 1982-86 (Table 11.3). Areas 12 and 20 were not covered by the survey, and sport landings from these areas are not documented. The 1986 landings were just below average at 168,000 pieces. The largest landings were from Area 16 for all but one year of the survey.

To provide a more meaningful analysis of commercial landings and LPUE, statistical areas within Area 4B were grouped by geographical area. There is no available information on stock delineation, although tagging experiments conducted in Puget Sound suggest that quillback and copper rockfish are fairly sedentary, at least as adults (Mathews and Barker 1983). The areas selected for detailed analysis were Port Hardy (Area 12), Campbell River (Area 13), Sechelt (Areas 15 and 16), and the Gulf Islands (Areas 14, 17, 18, and 19). Areas 20, 28, and 29 were excluded because of low line landings. Monthly landings for 1985 and 1986 for these statistical area groups are presented in Table 11.4. For Area 12, most of the landings occurred during the summer, June through October, probably because weather limits fishing effort at other times of year. Fishing effort was more uniformly spread over time for the other area groups. The lowest combined landings for Area 4B occurred in December.

A total of 439 vessels reported qualified landings from Area 4B in 1986, an increase of 19% over 1985 and 60% over 1984 (Table 11.5). The increase was spread over all area groups except Area 13. In Area 13, the number of vessels that reported landings has decreased by 31% since 1983. However, 32% of the vessels in Area 13 in 1986 had not previously reported landings from that area. In general, there is a high vessel turnover; 46% of the vessels that reported landings from Area 4B in 1986 had not previously reported landings from Area 4B. The highest proportion of "new" vessels in a statistical area group, 53%, occurred in Area 12.

A different approach was used to calculate LPUE in this assessment than reported in the previous assessment (Richards 1986). This choice was based on a comparison of LPUE trends for four different methods: (1) 20% qualification, (2) minimum 50 kg landing, (3) minimum 500 kg total annual landing in area 4B by that CFV, and (4) minimum 50 kg landing, plus a minimum 10 days fishing in area 4B by that CFV, including at least three landings. Line LPUE as calculated by the four methods showed the same general trends, and the values were almost identical for recent years when directed fishing on rockfish had increased. The minimum 50 kg landing method was selected because it depended on individual landing records only. A potential problem with a 20% qualification method was that a landing may be split over two or more sales slips if sales are made to more than one company (e.g. salmon sales to one company, rockfish sales to another). In this case the species composition of the landing would be misrepresented by the sales slip.

In general, LPUE is highly variable and a low proportion of the landings (except Area 12) and effort meet the qualification level for LPUE (Table 11.6). These proportions tend to increase over time for all areas, following the expansion of the targeted rockfish fishery. In Area 13, LPUE declined by 29% between 1981 and 1986 (Fig. 11.2b). The decline is coincident with the large landings from that area. In other areas, LPUE increased and landings increased or remained unchanged between 1985 and 1986 (Fig. 11.2a,c,d). These statistics are somewhat deceptive, as it is unlikely that stock size has increased in these areas. There is no evidence for sudden strong recruitment to the fishery.

One explanation for the increase in LPUE is a change in species composition of the landings. For example, the use of longline gear to target on yelloweye rockfish may have increased. Because of a large weight difference between yelloweye rockfish and quillback rockfish, an increase in the proportion of yelloweye rockfish in the line catch would inflate LPUE. Rockfish landings are not identified to species, so that the impact on LPUE of yelloweye rockfish or other large rockfish such as black rockfish cannot be determined. The species composition reported above is based on samples from handline vessels only.

11.2.3 Condition of the stock

Quillback rockfish stocks in Area 12 appear to be in good condition. The weight distribution of quillback rockfish in the Area 12 commercial samples is probably typical of a relatively unexploited stock (Table 11.7; Fig. 11.3), and is similar to the weight distribution from the 1986 research survey (Richards and Cass 1987). Although there was a decrease in mean weight between 1986-87, it is not clear whether this represents a decrease in mean weight of the stock or a market preference for smaller fish. Significant differences in mean fish size may occur among samples from different localities, seasons, and depths (Cass et al. 1986). The small mean weight from the 1985 area 12 sample is an anomaly and is indicative of the possible among-sample variance. Based on one 1986 sample aged to date, the mean age is 26 y with a range in age of 5-60 y.

In contrast to the Area 12 stocks, quillback rockfish stocks in Area 13 appear to be in relatively poor condition. There are two main types of evidence for a decline in size of quillback rockfish stocks in Area 13. First, based on the fishery data, landings, LPUE, and the number of vessels that reported landings in Area 13 have all declined over the past two-three years, in spite of increases in other areas. Second, there is a trend of decreasing mean fish weight, range of weight and modal weight for quillback rockfish landed in Area 13 between 1984-87 (Fig. 11.4). Modal weight decreased from 0.9 kg in 1984 to 0.3 kg in 1987, with weight at first recruitment to the fishery of 0.2 kg. As weight at 50% maturity is about 0.4 kg, and as fish as large as 0.9 kg may be immature, a high proportion of immature fish are landed by the fishery. The mean age from a 1984 and a 1986 sample from Area 13 and a 1986 sample from Area 17 was 18 y with a range of 4-55 y.

The change in quillback rockfish size distribution cannot be accounted for by either strong year classes recruiting to the fishery or by market restrictions. Quillback rockfish have slow growth rates (Fig. 11.5) and unlike the Area 12 samples, larger fish were absent in the latter Area 13 samples. Market restrictions apply to both Area 12 and Area 13. Although fishermen receive a better price for fish under 1.0 kg, a high percentage of larger fish were landed in Area 12 in 1987.

Less information is available for Sechelt and the Gulf Islands. Landings, LPUE, and the number of vessels that reported landings have been variable and there are no clear trends. There have been only two commercial samples collected from the Gulf Islands and none from Sechelt. Based on the two commercial samples (Table 11.7) and the research program (Richards and Cass 1987), the size distribution of quillback rockfish landed in these areas is intermediate between the distributions in Areas 12 and 13. Stocks in Sechelt and the Gulf Islands are probably in better condition than stocks in Area 13, although they have been heavily exploited over past years.

11.2.4 Yield options

Yield options were derived from historical all-species rockfish landings. A 75 t quota is listed as conservative for Area 12 and risk-sustainable for Area 13 because of the depletion that has already occurred in Area 13. The risk-sustainable option for the other areas is equivalent to landings in 1986. Although the discussion on stock condition deals only with quillback rockfish, the quota is intended for the inshore rockfish aggregate.

An extension of the winter closure has been suggested as an alternative to a quota. As the lowest landings in 1985-86 occurred for the month of December, extending the winter closure to December 1 from January 1 would have little effect on reducing fishing effort.

	Statistical area		
	12	13	14-20,28,29
Yield option 1. conservative	75 t	50 t	150 t
Yield option 2. risk-sustainable	100 t	75 t	200 t
Yield option 3. non-sustainable	>150 t	100 t	no limit

Table 11.1. Area 4B rockfish trawl landings (t) by statistical area, from groundfish data files, 1954-86.

	Statistical Area											Area 4B
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1954	5.0	0.3	29.5	0.0	0.0	7.7	11.4	0.7	60.7	0.0	4.8	120.1
1955	1.5	0.1	12.1	0.0	0.1	8.4	87.1	1.0	19.5	0.0	0.8	130.5
1956	5.6	0.6	15.3	0.0	0.0	9.1	4.3	17.2	18.1	0.0	1.4	71.6
1957	0.9	0.3	14.5	0.2	0.0	8.5	4.5	0.5	1.2	0.1	2.6	33.3
1958	1.2	0.8	8.0	0.0	0.0	9.9	2.0	3.1	27.2	0.0	1.2	53.3
1959	1.0	0.9	6.2	0.0	0.0	8.3	16.1	48.3	77.5	0.0	0.7	159.0
1960	0.8	0.3	7.2	0.0	0.1	6.1	8.3	7.6	144.8	0.0	0.7	175.7
1961	1.6	0.1	11.1	0.2	0.3	7.7	15.5	6.0	61.0	0.0	0.8	104.1
1962	2.4	0.8	9.0	0.0	0.5	9.1	12.6	0.3	56.9	0.0	1.0	92.7
1963	0.1	1.5	10.5	0.0	0.0	7.4	14.6	0.9	17.3	0.0	0.4	52.8
1964	0.3	5.0	5.7	0.0	0.0	8.9	20.1	4.5	71.4	0.0	1.2	117.1
1965	0.5	1.1	8.3	0.0	0.0	2.1	9.6	4.0	38.6	0.0	1.0	65.3
1966	2.2	0.0	7.5	0.0	0.0	1.7	7.8	0.8	118.8	0.0	0.0	138.8
1967	2.3	1.2	4.5	0.0	0.0	2.9	5.2	0.7	31.8	0.0	0.1	48.9
1968	1.4	0.0	6.3	0.0	0.0	21.7	4.2	0.9	64.4	0.0	0.1	98.9
1969	0.8	1.2	9.1	0.0	0.0	4.4	5.4	2.4	75.5	0.0	0.3	99.0
1970	0.0	0.0	5.9	0.0	0.0	12.5	7.8	0.1	75.9	0.0	0.2	102.4
1971	0.1	0.1	6.4	0.0	0.0	9.1	7.0	0.4	10.5	0.0	0.6	34.2
1972	0.0	0.0	6.1	0.0	0.0	7.4	2.9	0.1	29.1	0.0	0.0	45.6
1973	0.5	1.9	3.1	0.0	0.0	12.1	2.9	0.0	3.5	0.0	0.1	24.0
1974	0.0	0.2	5.3	0.0	0.0	5.6	5.7	0.1	4.1	0.0	0.6	21.7
1975	0.1	1.8	4.0	0.0	0.0	2.3	7.6	2.4	10.9	0.0	0.0	29.1
1976	0.2	1.0	3.3	0.0	0.0	2.0	9.1	1.1	14.3	0.0	0.0	31.1
1977	1.2	0.8	5.2	0.0	0.0	2.6	7.9	2.0	10.5	0.0	0.0	30.1
1978	9.8	0.4	5.6	0.0	0.0	1.7	12.3	5.7	16.6	0.0	0.1	52.0
1979	0.4	0.0	3.8	0.0	0.0	3.6	15.7	17.5	82.9	0.0	0.4	124.2
1980	0.1	0.1	1.2	0.0	0.0	5.2	6.4	6.1	20.7	0.0	0.1	39.8
1981	0.6	0.0	1.8	0.0	0.0	2.6	11.0	15.8	17.9	0.0	1.5	51.1
1982	0.0	0.1	2.9	0.0	0.1	5.2	9.7	11.5	19.2	0.0	0.2	48.7
1983	2.7	0.1	0.9	0.0	0.0	3.5	11.1	4.2	4.8	0.0	0.1	27.4
1984	0.1	0.0	1.1	0.0	0.0	1.8	15.4	7.7	12.3	0.0	0.4	38.8
1985	0.2	0.0	0.9	0.0	0.0	2.2	6.6	6.8	8.5	0.0	0.1	25.2
1986	0.0	0.1	1.1	0.0	0.0	4.3	5.0	1.4	33.8	0.0	0.0	45.6

Table 11.2. Area 4B rockfish handline/troll and longline landings (t) by statistical area, from British Columbia catch statistics, Annual Reports, 1954-86.

	Statistical Area											Area 4B
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1954	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1955	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1956	6.8	2.0	0.2	1.0	5.0	19.0	5.5	0.1	0.1	0.0	0.2	39.9
1957	5.7	6.1	2.5	2.8	14.5	26.0	7.0	6.5	0.0	0.1	1.1	72.4
1958	8.0	10.8	9.8	6.0	15.4	29.3	15.8	6.3	3.2	0.0	2.0	106.6
1959	13.2	16.4	9.3	10.7	10.9	36.4	4.0	3.9	0.5	0.1	0.7	106.1
1960	10.1	20.1	4.8	11.8	11.2	19.8	3.5	3.2	0.9	0.4	0.1	86.0
1961	10.4	16.9	6.5	2.7	4.9	16.2	3.2	1.4	0.6	0.1	1.5	64.5
1962	52.8	15.1	4.7	5.8	3.1	19.7	2.4	2.5	0.6	0.2	0.5	107.5
1963	39.1	7.8	3.7	1.6	6.2	16.4	2.8	0.9	0.2	0.0	0.2	78.8
1964	11.1	4.6	2.1	0.9	12.8	8.8	2.8	1.1	0.7	0.0	0.1	45.1
1965	10.2	3.5	2.1	0.1	10.3	9.3	3.3	0.4	0.1	0.0	0.3	39.6
1966	4.2	3.6	3.8	0.5	13.0	4.1	4.1	0.2	0.1	0.1	0.0	33.8
1967	9.9	7.6	5.9	3.4	16.7	6.3	1.9	0.1	0.1	0.0	0.0	51.9
1968	11.8	8.2	5.0	1.0	19.0	10.3	1.4	0.2	0.1	0.0	0.0	57.0
1969	25.3	12.0	3.8	3.5	16.6	8.8	4.2	0.3	0.9	0.0	0.1	75.6
1970	23.8	16.9	4.0	5.0	9.8	16.1	1.5	0.6	0.8	0.0	0.0	78.9
1971	28.6	9.4	2.7	5.1	6.8	12.2	1.0	0.3	0.0	0.0	0.0	66.1
1972	26.3	14.1	5.0	4.5	11.8	12.2	0.9	0.5	0.0	7.0	0.0	82.3
1973	30.8	11.4	2.7	7.2	14.9	10.5	1.4	0.0	0.0	12.3	0.0	91.2
1974	8.6	7.3	3.2	8.2	2.8	12.2	2.8	0.0	0.0	0.8	0.0	45.7
1975	5.9	5.9	2.3	6.3	1.9	9.1	4.5	0.5	0.0	1.7	0.0	37.9
1976	10.9	10.4	5.0	7.7	2.7	7.3	2.7	0.0	0.9	3.3	0.0	50.9
1977	55.8	17.7	9.1	15.9	5.4	10.9	15.0	2.7	0.9	13.8	1.0	148.1
1978	21.0	30.0	7.0	15.0	19.0	29.0	32.0	5.0	1.0	1.0	3.0	163.0
1979	40.0	63.0	12.0	16.0	22.0	37.0	46.0	5.0	1.0	2.0	5.0	249.0
1980	27.0	43.0	10.0	12.0	20.0	20.0	35.0	5.0	2.0	3.0	0.0	177.0
1981	20.7	55.6	12.0	27.2	29.7	20.8	40.1	3.1	0.0	0.4	1.4	211.0
1982	21.5	106.3	9.0	74.5	34.2	10.0	18.5	2.0	0.0	0.2	1.7	277.9
1983	8.4	186.6	7.3	11.3	28.4	14.2	15.7	1.8	0.2	0.6	0.3	274.8
1984	32.7	198.0	3.3	13.3	22.8	38.0	23.6	7.7	2.0	0.2	1.4	342.6
1985	106.3	153.1	4.9	17.6	22.9	84.5	34.7	9.0	1.4	0.0	1.7	436.1
1986	136.2	140.6	18.2	24.8	31.6	59.4	28.6	23.7	9.3	0.2	2.5	475.1

Table 11.3. Sport landings of rockfish (thousands of pieces) in the Strait of Georgia by statistical area, 1982-86, as estimated by the creel survey.

	Statistical Area									
Year	13	14	15	16	17	18	19	28	29	Total
1982[a]	25.0	15.6	4.5	38.6	26.1	29.8	12.0	36.1	8.7	194.7
1983	37.2	17.9	3.8	42.0	23.4	23.6	37.3	14.8	9.1	209.1
1984	22.7	14.4	4.3	16.1	35.3	20.3	26.7	10.8	8.0	158.7
1985	14.4	12.4	1.7	38.5	20.9	12.1	20.3	7.2	6.5	134.0
1986	21.2	20.7	2.7	48.9	18.4	12.9	28.6	7.0	7.2	167.8

[a] Mean of 1980-82 estimates.

Table 11.4. Combined monthly landings (t) for 1985 and 1986 by statistical area group.

Month	Area 12	Area 13	Gulf Is.	Sechelt	Combined
January	4.45	25.30	14.07	9.45	34.75
February	7.25	25.50	21.93	13.72	39.22
March	8.05	28.39	22.74	10.76	39.15
April	13.79	23.18	30.76	6.09	29.27
May	16.30	20.02	38.82	5.73	25.75
June	40.42	23.38	33.33	9.07	32.45
July	25.10	20.10	18.71	6.49	26.60
August	30.82	26.99	23.65	6.44	33.43
September	30.09	33.21	17.43	9.46	42.68
October	37.97	31.68	27.97	8.16	39.85
November	18.78	21.88	16.25	5.18	27.06
December	6.10	14.33	12.84	5.45	19.78

Table 11.5. Number of vessels that reported 50 kg qualified landings and the percent of vessels that had not previously reported qualified landings in the area, by statistical area group and for Area 4B combined.

	Area 12		Area 13		Gulf Is.		Sechelt		Combined	
Year	N	%	N	%	N	%	N	%	N	%
1979[a]	71	-	98	-	162	-	65	-	360	-
1980	45	53	65	54	117	68	54	81	259	59
1981	42	67	86	67	88	65	60	70	255	58
1982	47	70	114	59	67	54	98	62	271	49
1983	37	57	127	46	71	51	43	37	256	37
1984	60	75	125	34	81	60	41	37	274	42
1985	65	62	101	29	86	51	42	45	369	50
1986	66	53	87	32	97	41	47	49	439	46

[a] First year of data in which vessels could be identified by CFV.

Table 11.6. Total landings (t), LPUE (kg/d), effort (days), and the proportions of total line landings and total line effort that met the 50 kg qualification level by statistical area group. Effort is calculated from the ratio of LPUE to total landings.

a) Area 12, Port Hardy

Year	Landings (t)	LPUE (kg/d)	Effort (d)	Prop. Wt.	Prop. Effort
1967	12.2	89.40	136	0.919	0.332
1968	13.2	34.29	385	0.928	0.539
1969	26.1	64.00	408	0.900	0.603
1970	23.8	72.25	329	0.938	0.478
1971	28.7	65.73	437	0.981	0.773
1972	26.3	41.24	638	0.964	0.715
1973	31.3	102.42	306	0.965	0.619
1974	8.6	36.63	235	0.907	0.589
1975	6.0	36.19	166	0.950	0.704
1976	11.1	47.49	234	0.849	0.357
1977	57.0	80.75	706	0.957	0.469
1978	30.8	52.08	591	0.905	0.381
1979	40.4	54.96	735	0.957	0.551
1980	27.1	48.70	556	0.956	0.524
1981	21.3	57.28	372	0.933	0.332
1982	21.5	54.90	392	0.944	0.380
1983	11.1	63.09	176	0.911	0.256
1984	32.8	78.88	416	0.972	0.614
1985	106.5	70.10	1519	0.992	0.919
1986	136.2	85.35	1596	0.997	0.957

b) Area 13, Campbell River.

Year	Landings (t)	LPUE (kg/d)	Effort (d)	Prop. Wt.	Prop. Effort
1967	8.8	47.75	184	0.330	0.055
1968	8.2	60.73	135	0.329	0.050
1969	13.2	106.39	124	0.596	0.095
1970	16.9	59.62	283	0.461	0.122
1971	9.5	61.23	155	0.344	0.070
1972	14.1	45.78	308	0.541	0.123
1973	13.3	63.73	209	0.661	0.164
1974	7.5	52.23	144	0.393	0.076
1975	7.7	81.31	95	0.516	0.061
1976	11.4	49.83	229	0.568	0.105
1977	18.5	51.12	362	0.555	0.106
1978	30.4	56.33	540	0.647	0.167
1979	63.0	66.90	942	0.709	0.186
1980	43.1	57.71	747	0.667	0.146
1981	55.6	62.84	885	0.774	0.279
1982	106.4	62.21	1710	0.898	0.453
1983	186.7	51.52	3624	0.967	0.809
1984	198.0	47.30	4186	0.983	0.900
1985	153.1	46.36	3302	0.981	0.910
1986	140.7	44.59	3156	0.983	0.942

c) Areas 15 and 16, Sechelt

Year	Landings (t)	LPUE (kg/d)	Effort (d)	Prop. Wt.	Prop. Effort
1967	20.1	56.05	359	0.436	0.108
1968	20.0	76.31	262	0.368	0.075
1969	20.1	74.65	269	0.373	0.067
1970	14.8	47.53	311	0.286	0.061
1971	11.9	32.66	364	0.253	0.059
1972	16.3	28.19	578	0.248	0.068
1973	22.1	67.74	326	0.642	0.179
1974	11.0	61.03	180	0.583	0.126
1975	8.2	24.66	333	0.431	0.129
1976	10.4	39.28	265	0.556	0.118
1977	21.3	70.99	300	0.759	0.203
1978	34.0	60.11	566	0.851	0.307
1979	38.0	84.24	451	0.834	0.238
1980	32.0	65.14	491	0.901	0.340
1981	56.9	104.94	542	0.856	0.375
1982	108.8	79.94	1361	0.897	0.523
1983	39.7	63.68	623	0.761	0.370
1984	36.1	56.06	644	0.760	0.457
1985	40.5	84.69	478	0.946	0.715
1986	56.4	89.49	630	0.934	0.568

d) Areas 14, 17, 18 and 19, Gulf Islands

Year	Landings (t)	LPUE (kg/d)	Effort (d)	Prop. Wt.	Prop. Effort
1967	27.5	40.71	675	0.167	0.024
1968	50.0	31.51	1587	0.159	0.027
1969	38.4	27.89	1377	0.312	0.068
1970	48.5	38.03	1275	0.403	0.078
1971	39.1	58.03	674	0.415	0.052
1972	35.1	25.39	1382	0.152	0.030
1973	32.7	36.78	889	0.414	0.089
1974	34.9	28.71	1216	0.553	0.171
1975	32.7	58.92	555	0.606	0.105
1976	30.5	49.32	618	0.298	0.050
1977	55.4	55.17	1004	0.681	0.182
1978	98.3	53.68	1831	0.754	0.254
1979	140.6	53.45	2630	0.817	0.320
1980	88.9	50.82	1749	0.816	0.323
1981	107.2	69.51	1542	0.872	0.304
1982	68.8	42.10	1634	0.752	0.264
1983	58.7	42.51	1381	0.859	0.389
1984	98.6	45.66	2159	0.894	0.607
1985	149.6	64.36	2324	0.973	0.809
1986	141.7	77.28	1833	0.969	0.767

Table 11.7. Number of commercial quillback rockfish samples and mean weight (g) with standard error and sample size by statistical area and year.

			Males			Females			Combined Sexes		
Area	Year	No. of Samples	n	mean	SE	n	mean	SE	n	mean	SE
12	85	1	140	811	19	121	790	20	261	801	14
12	86	2	220	878	28	261	1156	32	481	1029	22
12	87	1	144	965	36	157	995	37	301	980	26
13	84	4	354	837	18	436	921	19	790	884	13
13	85	2	466	654	13	339	709	18	805	677	11
13	86	2	294	655	17	313	742	20	607	700	13
13	87	1	135	545	21	121	532	24	256	539	15
14	86	1	21	650	35	35	685	31	56	672	23
17	86	1	101	852	31	164	1025	29	265	959	22

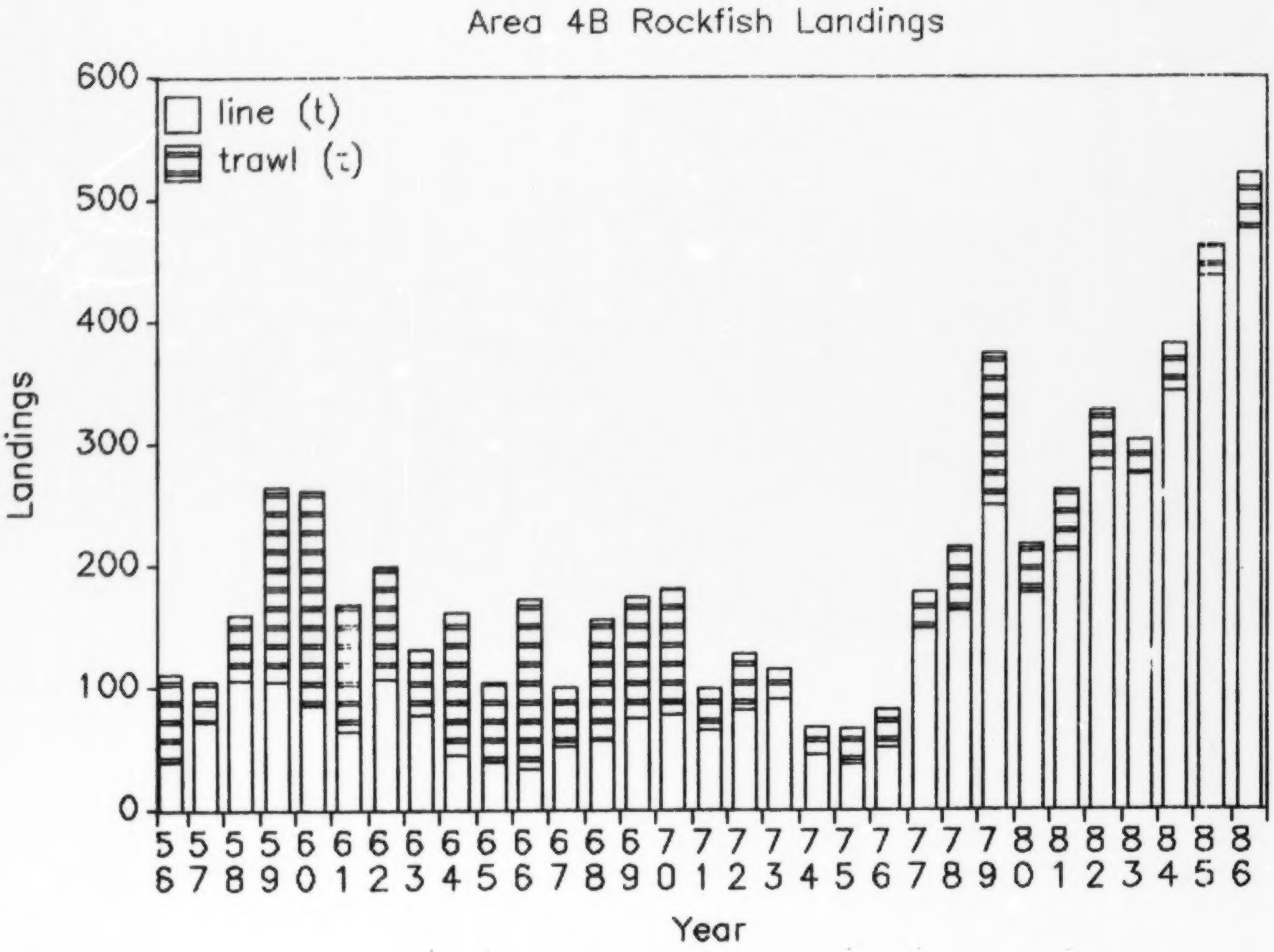

Fig. 11.1. Rockfish line landings and trawl landings for Area 4B, 1956-86.

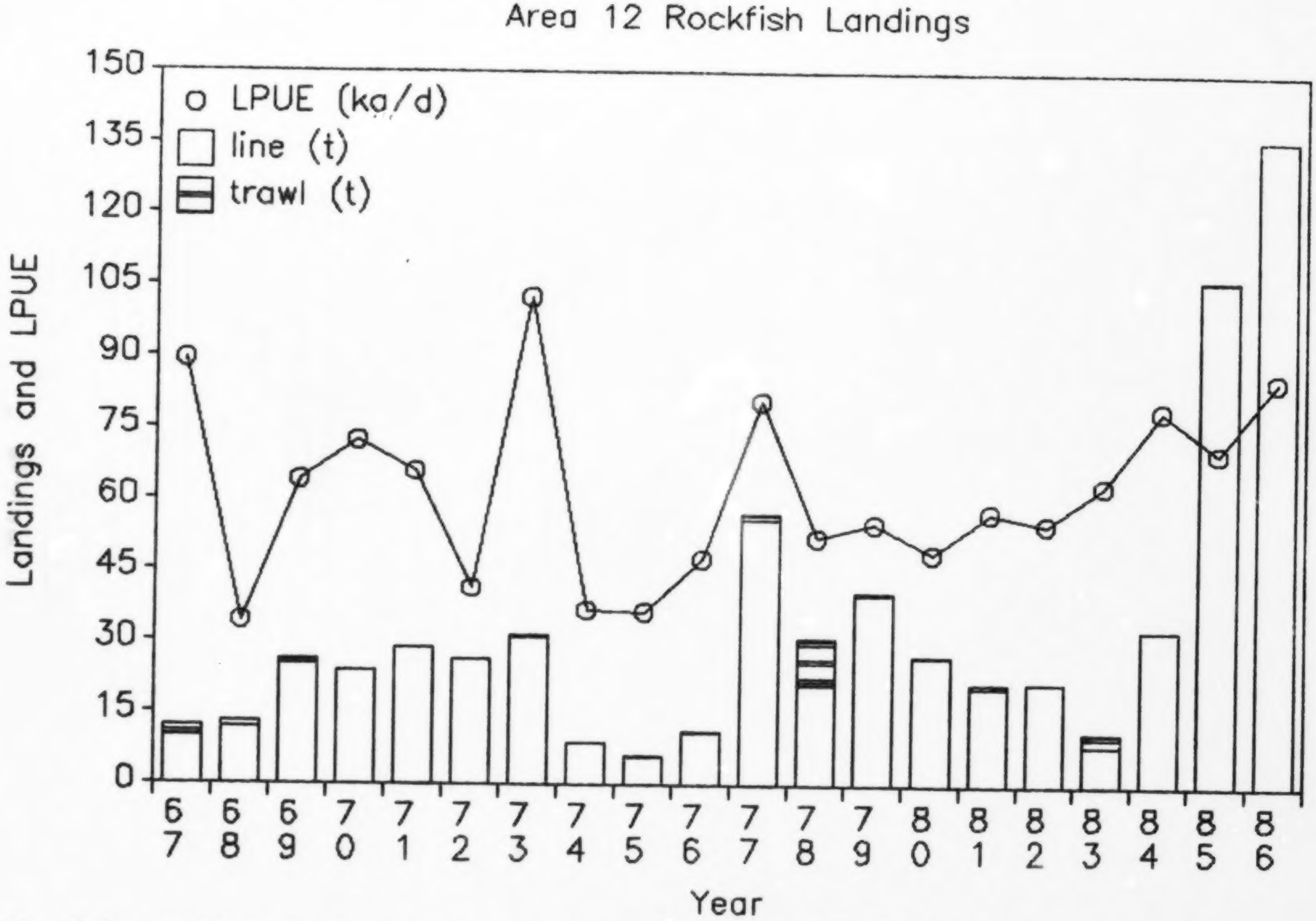

Fig. 11.2a. Rockfish line landings, trawl landings, and qualified LPUE for Area 12.

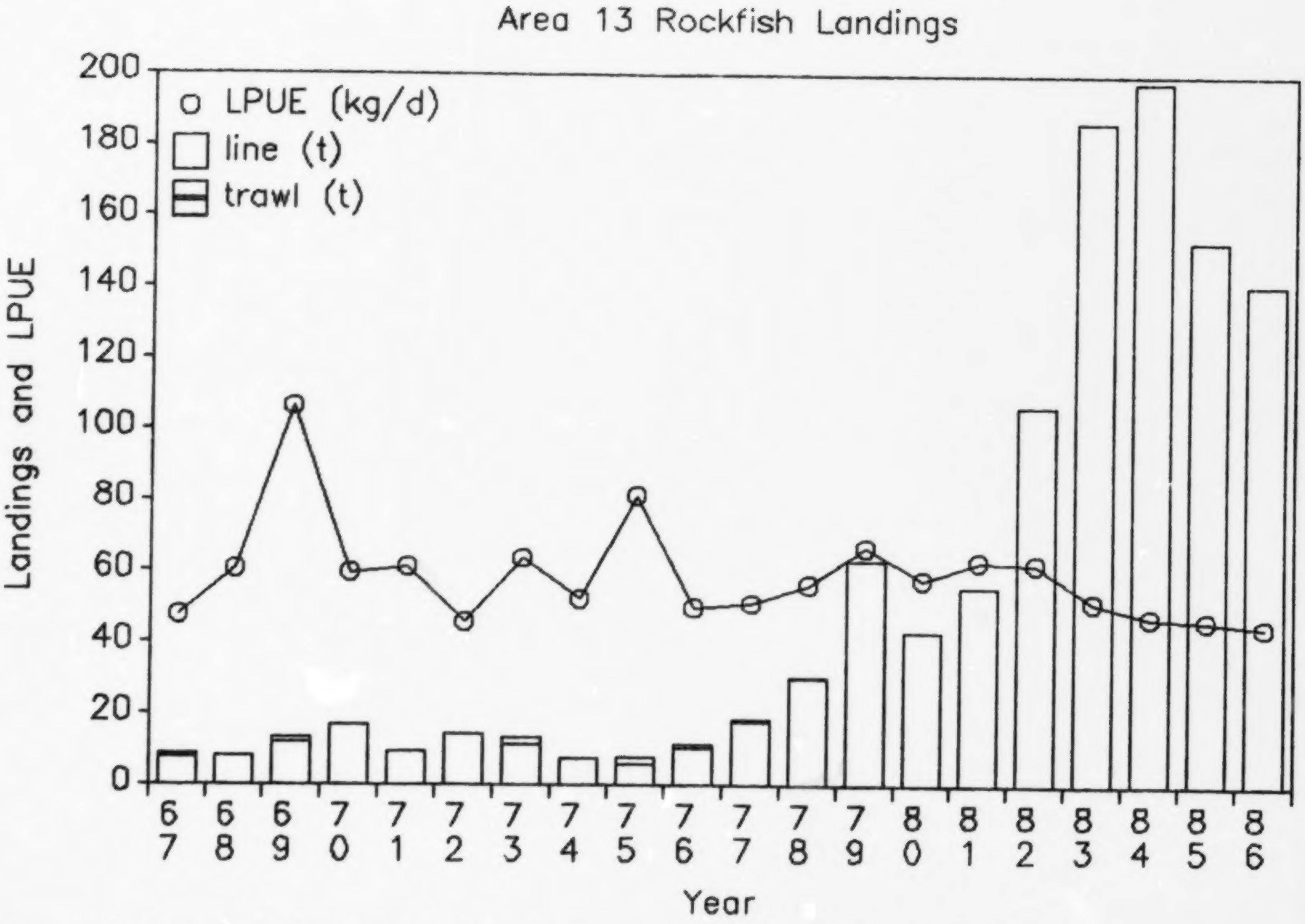

Fig. 11.2b. Rockfish line landings, trawl landings, and qualified LPUE for Area 13.

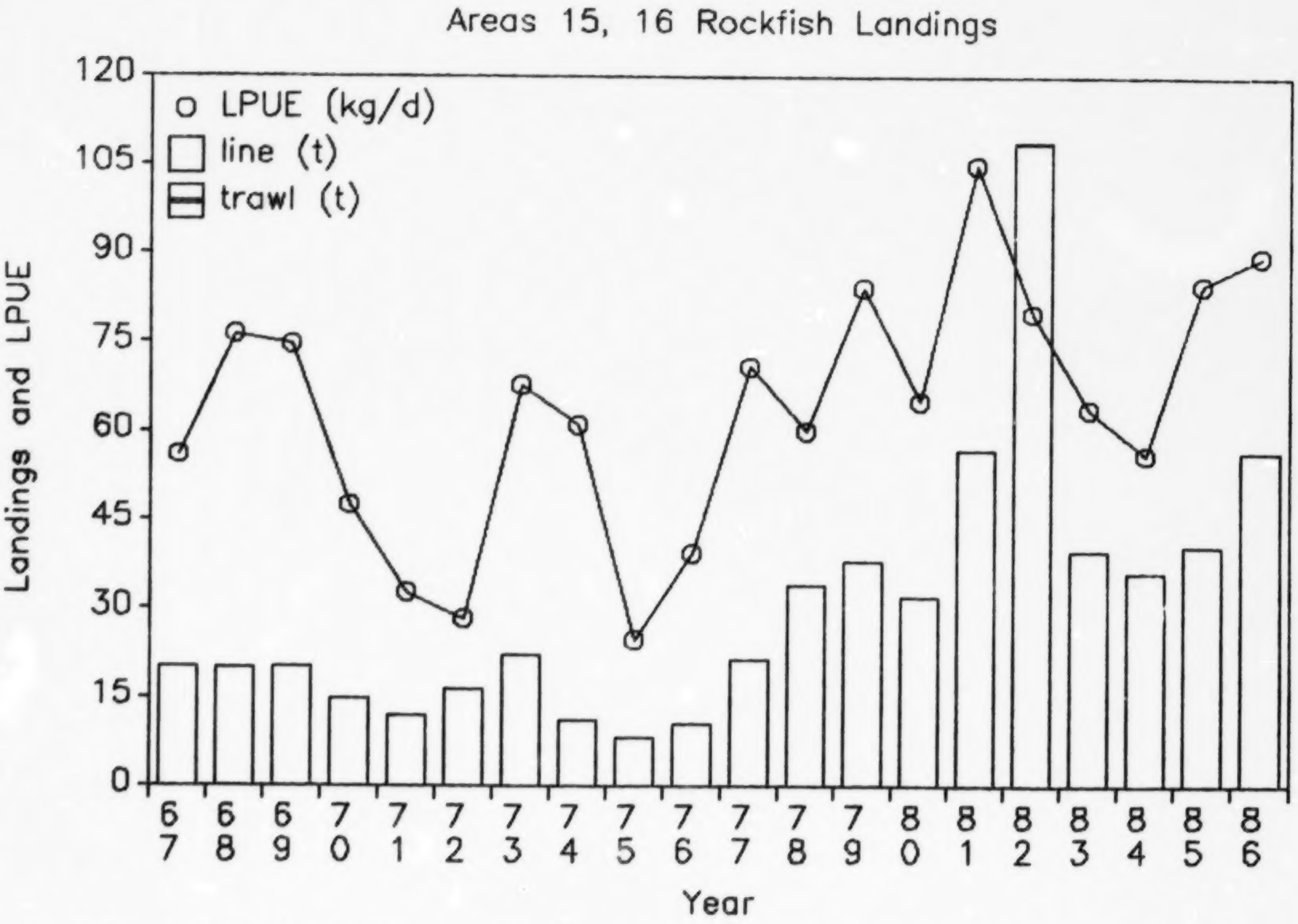

Fig. 11.2c. Rockfish line landings, trawl landings, and qualified LPUE for Areas 15-16.

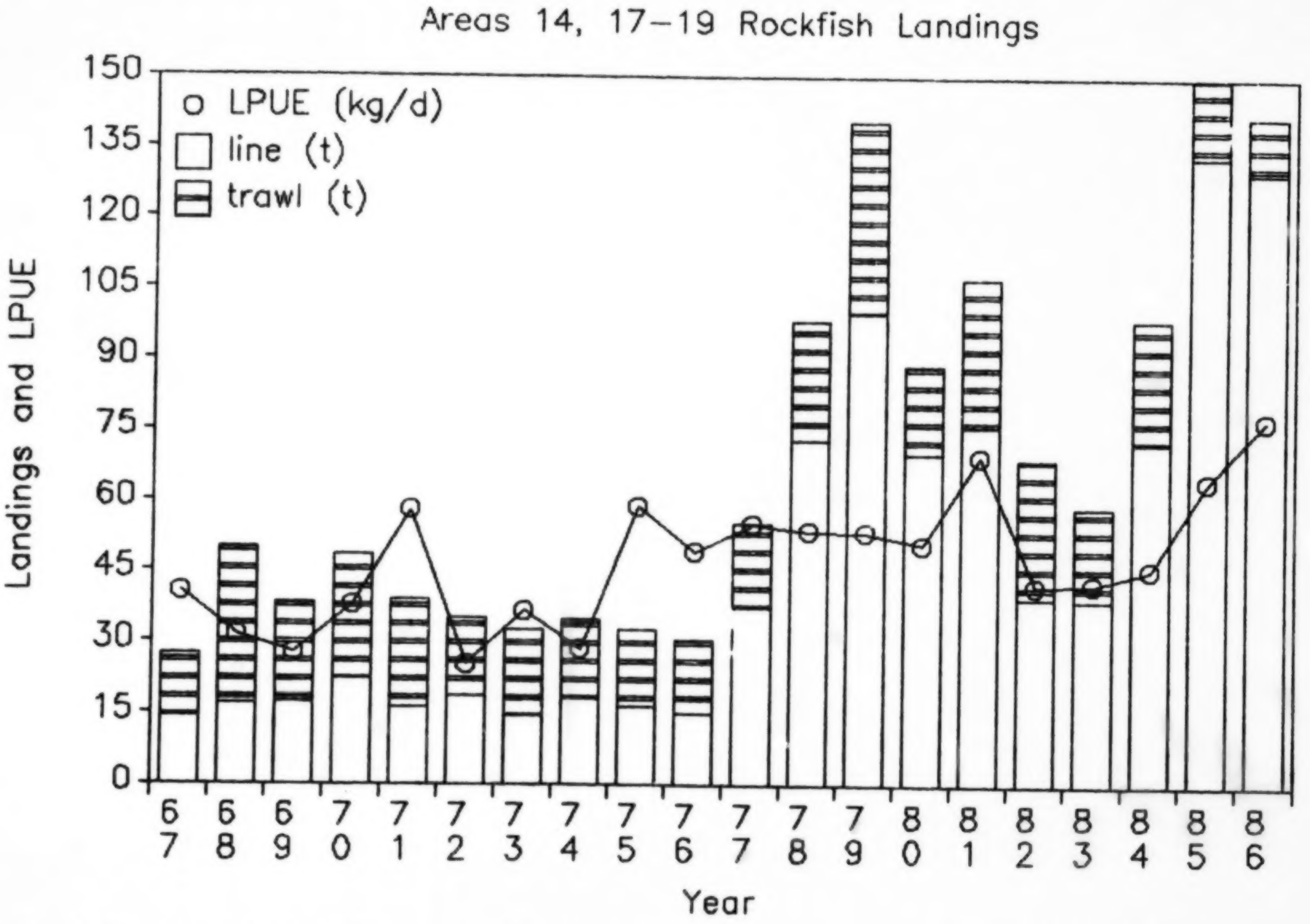

Fig. 11.2d. Rockfish line landings, trawl landings, and qualified LPUE for Areas 14, 17-19, 1967-86.

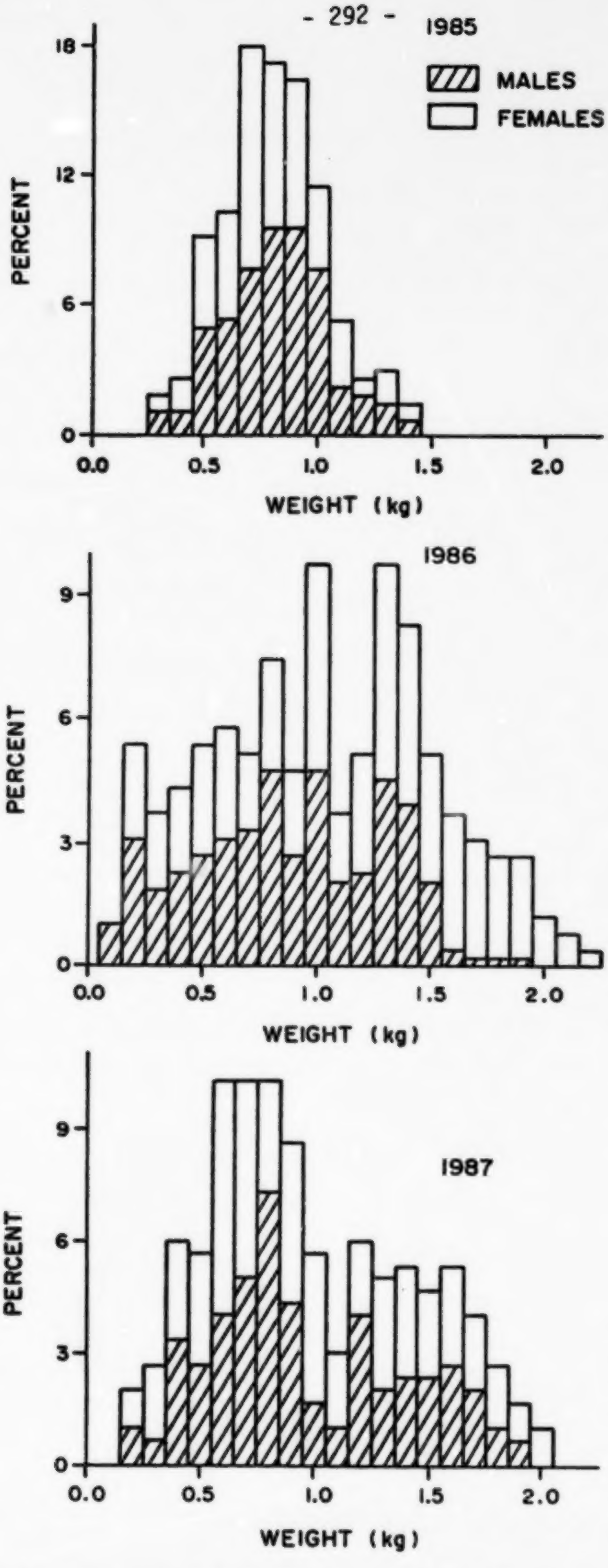

Fig. 11.3. Weight frequency distributions of quillback rockfish commercial samples from Area 12, 1985-87.

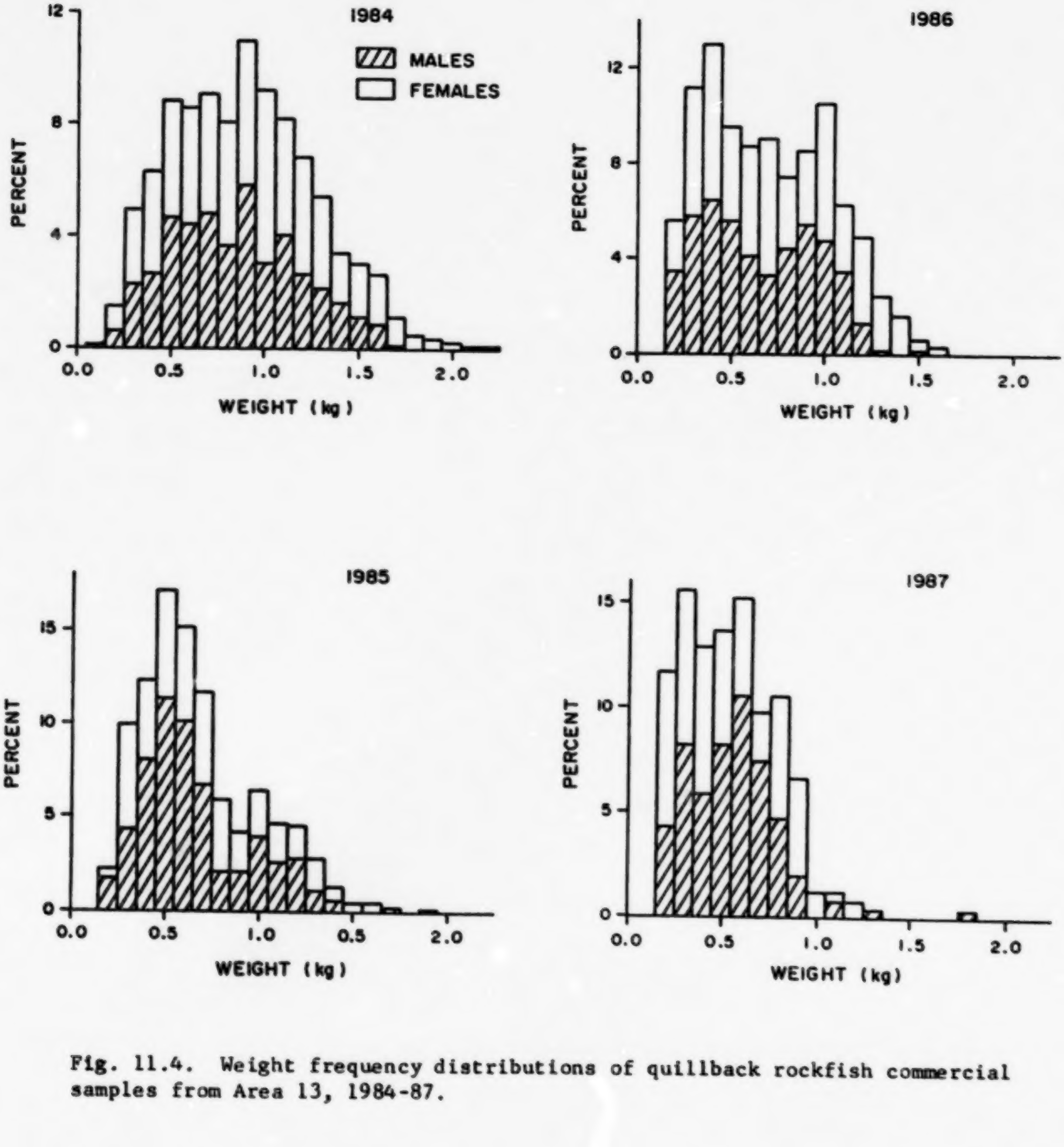

Fig. 11.4. Weight frequency distributions of quillback rockfish commercial samples from Area 13, 1984-87.

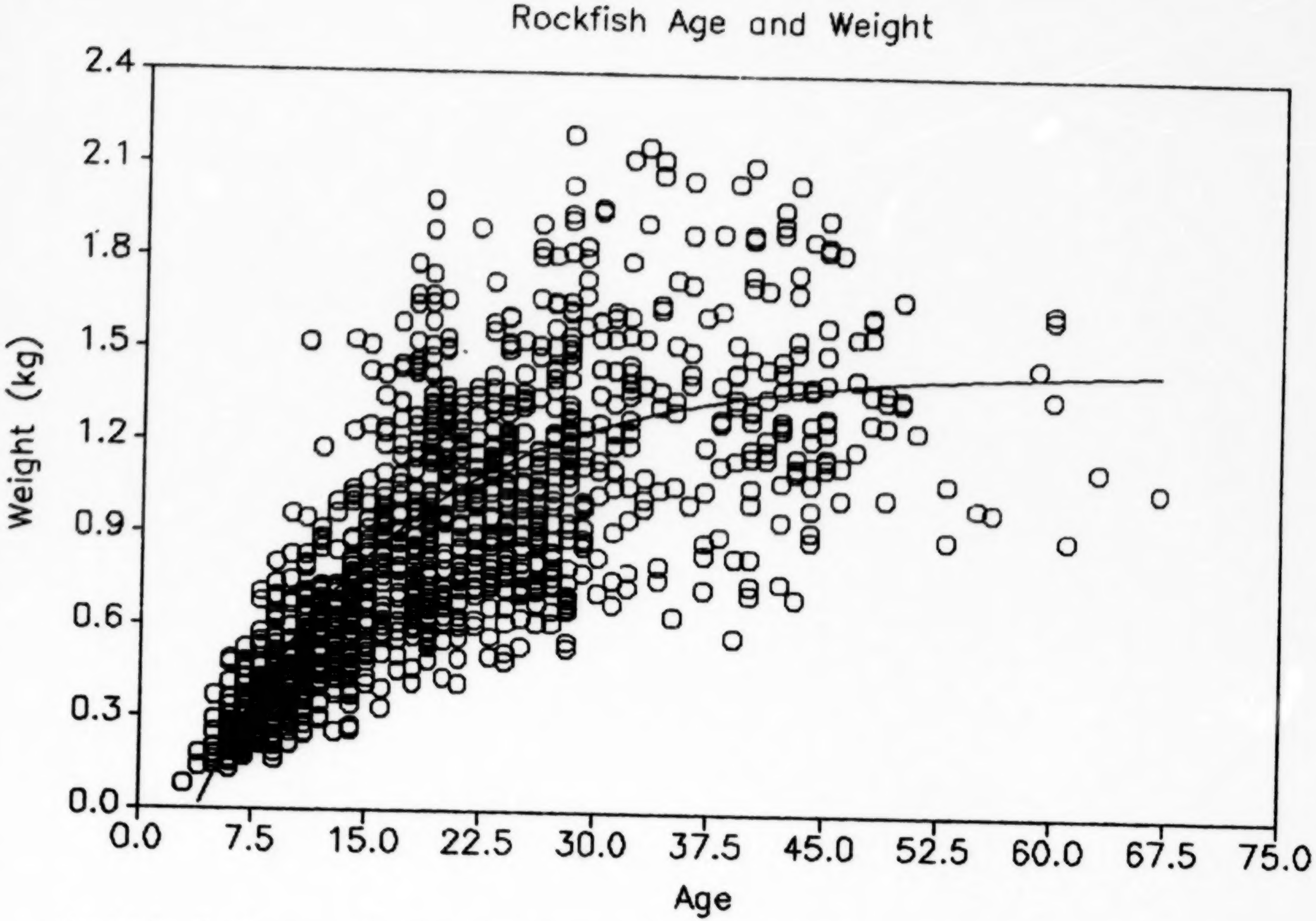

Fig. 11.5. Weight-at-age for Area 12 research and commercial samples, and Area 13 and 17 commercial samples, with the von Bertalanffy growth curve (W_∞=1456 g, K=0.07412, t_0=3.84) for the Area 12 samples.

REFERENCES

Archibald, C. P., D. Fournier, and B. M. Leaman. 1983. Reconstruction of stock history and development of rehabilitation strategies for Pacific ocean perch in Queen Charlotte Sound, Canada. N. Am. J. Fish. Manage. 3: 283-294.

Archibald C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-1979. Can. Tech. Rep. Fish. Aquat. Sci. 1048: 57 p.

Bailey, K. M. 1981. Larval transport and recruitment of Pacific hake, Merluccius productus. Mar. Ecol. Prog. Ser. 6: 1-9.

Bargmann, G. G. 1983. A recommendation for a 26 inch minimum size limit for lingcod in Puget Sound. Washington Department of Fisheries. Briefing Report.

Beamish, R. J. and D. Chilton. 1977. Age determination of lingcod (Ophiodon elongatus) using dorsal fin rays and scales. J. Fish. Res. Board Can. 34: 1305-1313.

Braaten, D. O. 1969. Robustness of the DeLury population estimator. J. Fish. Res. Board Can. 26: 339-355.

Cass, A. J. 1985. Lingcod. In: Tyler, A. V. and G. A. McFarlane [eds.], Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 25-56.

Cass, A. J. 1987. Lingcod. In: Tyler, A. V. and M. W. Saunders [eds.], Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 13-22.

Cass, A. J. and R. J. Beamish. 1983. First evidence of validity of the fin-ray method of age determination for marine fishes. North Am. J. Fish. Manage. 3: 182-188.

Cass, A. J., R. J. Beamish, and G. A. McFarlane. In prep. The fishery and biology of lingcod. Can. Spec. Publ. Fish. Aquat. Sci.

Cass, A. J., E. Cameron, and I. Barber. 1983. Lingcod tagging study off southwest Vancouver Island, M/V PACIFIC EAGLE --July 14-27, 1982. Can. Data Rep. Fish Aquat. Sci. 406: 84 p.

Cass, A. J., L. J. Richards, and J. T. Schnute. In prep. A summary of fishery and biological data for lingcod off the southwest coast of Vancouver Island. Can. Tech. Rep. Fish. Aquat. Sci.

Cass, A. J., L. J. Richards, and J. R. Selsby. 1986. A summary of rockfish samples collected from the commercial handline fishery in statistical area 13 between July 1984 and March 1985. Can. MS Rep. Fish. Aquat. Sci. 1881: 49 p.

Cass, A. J., J. R. Selsby, and L. J. Richards. 1986. Lingcod maturity cruise off southwest Vancouver Island and in Queen Charlotte Sound, R/V G. B. REED, August 20-September 5, 1985. Can. Data Rep. Fish. Aquat. Sci. 594: 78 p.

Chatwin, B. M. 1956. Further results from tagging experiments on lingcod. Fish. Res. Board Can. Progr. Rep. 107: 19-21.

Chilton D. E. and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60: 102 p.

Davenport, D. 1985. Biological observations of the foreign hake fishery for 1983. Can. MS Rep. Fish. Aquat. Sci. 1811: 15 p.

Fargo, J. 1985. Flatfish. In: Tyler, A. V. and G. A. McFarlane [eds.]. 1987. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 57-115.

Fargo, J. 1987. Flatfish. In: Tyler, A. V. and M. W. Saunders [eds.]. Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 156 p.

Fargo, J., L. A. Lapi, J. E. Richards, and M. Stocker. 1981. Turbot biomass survey of Hecate Strait, June 9-20, 1980. Can. MS Rep. Fish. Aquat. Sci. 1630: 84 p.

Fargo, J. and S. J. Westrheim. 1987. Results, through 1985, of the rock sole (Lepidopsetta bilineata) tagging experiments in Hecate Strait (British Columbia) during April-May 1982 with regard to stock delineation. Can. MS Rep. Fish. Aquat. Sci. 1912: 51 p.

Forrester, C. R. and J. A. Thomson. 1969. Population studies on the rock sole (Lepidopsetta bilineata) of northern Hecate Strait, British Columbia. Fish. Res. Board Can. Tech. Rep. 108: 104 p.

Foucher, R. P. 1987. Standardized landing statistics for Pacific cod (Gadus macrocephalus) and important shelf co-habitants from Hecate Strait, Queen Charlotte Sound and off southwest Vancouver Island, 1956-85. Can. Data Rep. Fish. Aquat. Sci. 620: 81 p.

Foucher, R. P. and D. Fournier. 1982. Derivation of Pacific cod age composition using length-frequency analysis. N. Amer. J. Fish. Manage. 2: 276-284.

Foucher, R. P. and S. J. Westrheim. 1984. Numbers landed-at-age and associated standardized landing statistics for Pacific cod (Gadus macrocephalus) from important area-time cells off southwest Vancouver Island and in Queen Charlotte Sound and Hecate Strait, 1956-1982. Can. MS Rep. Fish. Aquat. Sci. 1775: 59 p.

Fournier, D. A. and P. A. Breen. 1983. Estimation of abalone mortality rates with growth analysis. Trans. Am. Fish. Soc. 112: 403-411.

Fraidenburg, M. E., S. J. Westrheim, and R. L. Demory. 1978. The status of Pacific ocean perch (Sebastes alutus) stocks off British Columbia, Washington, and Oregon in 1977. Unpublished report of the Tech. Subcomm., Int. Groundfish Comm. 27 p.

Francis, R. C. 1983. Population and trophic dynamics of Pacific hake (Merluccius productus). Can. J. Fish. Aquat. Sci. 40: 1925-1943.

Francis, R. C. 1985. Status of the Pacific Hake Resource and Recommendations for Management in 1986. (Document submitted to the Pacific Fisheries Management Council, Portland, Oregon, October 1985). Northwest and Alaska Fisheries Center, Nat'l. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA.

Francis, R. C. 1986. Two fishery biology problems in west coast groundfish management. N. Am. J. Fish. Manage. 6: 453-462.

Francis, R. C. and A. Hollowed. 1984. Status of the Pacific hake resource and recommendations for management in 1985. In PFMC, Status of the Pacific Coast Groundfish Fishery and Recommendations for Management in 1985.

Francis, R. C., G. A. McFarlane, A. B. Hollowed, G. L. Swartzman, and W. M. Getz. 1984. Status and management of the Pacific hake (Merluccius productus) resource and fishery off the west coast of the United States and Canada. U.S. Dept. Comm., NOAA, NMFS, Northwest and Alaska Fisheries Center Processed Report 84-18.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Getz, W. M. and G. L. Swartzman. 1981. A probability transition matrix model for yield estimation in fisheries with highly variable recruitment. Can. J. Fish. Aquat. Sci. 38: 847-855.

Golden, J. T. and R. L. Demory. 1984. A progress report on the status of canary rockfish (Sebastes pinniger) in the INPFC Vancouver, Columbia and Eureka Areas in 1984. In: Status of Pacific Coast Groundfish Fishery and Recommendations for Management in 1985. Pacific Fishery Management Council, Portland, Oregon.

Gulland, J. A. 1961. Fishing and the stocks of fish at Iceland. U.K. Min. Agric. Fish. Food. Fish. Invest. (Ser. 2) 23(4): 52 p.

Gulland, J. A. 1969. Manual of methods for fish stock assessment. Part I. Fish population analysis. FAO (Food Agric. Organ. U.N.) Mar. Fish. Sci. 4: 154 p.

Gulland, J. A. 1970. The fish resources of the oceans. FAO Fish. Tech. Pap. 97: 425 p.

Gulland, J. A. 1983. Fish Stock Assessment: A manual of basic methods FAO/Wiley series on food and agriculture. Wiley & Sons, 223 p.

Gunderson, D. R. 1977. Population biology of Pacific ocean perch, Sebastes alutus, stocks in the Washington-Queen Charlotte Sound region and their response to fishing. Fish. Bull. 75: 369-403.

Gunderson, D. R. 1978. Results of cohort analysis for Pacific ocean perch stocks off British Columbia, Washington, and Oregon and an evaluation of alternative rebuilding strategies for these stocks. Report to the Tech. Subcomm., Int. Groundfish Comm., Menlo Park, CA. 13 p.

Gunderson, D. R. 1981. An updated cohort analysis for Pacific ocean perch stocks off Washington and Oregon. Pac. Fish. Manage. Coun. Rep., Portland, Oregon. 29 p.

Gunderson, D. R. 1984. The great widow rockfish hunt of 1980-1982. N. Am. J. Fish. Manage. 4: 465-468.

Gunderson, D. R., S. J. Westrheim, R. L. Demory, and M. E. Fraidenburg. 1977. The status of Pacific ocean perch (Sebastes alutus) stocks off British Columbia, Washington, and Oregon in 1974. Fish. Mar. Serv. Tech. Rep. 690: 63 p.

Hand, C. M. and L. J. Richards. In prep. Hook and line survey of lingcod stocks in the Gulf Islands region (MSA 17) of the Strait of Georgia, January and February, 1987. Can MS Rep. Fish Aquat Sci.

Hightower, J. E and G. D. Grossman. 1987. Optimal policies for rehabilitation of overexploited fish stocks using a deterministic model. Can. J. Fish. Aquat. Sci. 44: 803-810.

Hollowed, A. B., S. Adlerstein, R. C. Francis, and M. W. Saunders. In prep. Status of the Pacific Whiting Resource in 1987 and Recommendations for Management in 1988. NOAA Tech. Memo. NMFS F/NWC.

Hollowed, A. B. and R. C. Francis. 1986. Status of the Pacific whiting resource and recommendations for management in 1987. NOAA Tech. Memo. NMFS F/NWC - 118, 29 p.

Ito, D. H., D. K. Kimura, and M. E. Wilkins. 1987. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1986. NOAA Tech. Memor. NMFS F/NWC-113. 50 p.

Ketchen, K. S. 1964. Preliminary results of studies on growth and mortality of Pacific cod (Gadus macrocephalus) in Hecate Strait, British Columbia. J. Fish. Res. Board. Can. 21(5): 1051-1067.

Ketchen, K. S. 1981. Reconstruction of Pacific ocean perch (*Sebastes alutus*) stock history in Queen Charlotte Sound. Part II. Catch per unit effort as a measure of abundance. Can. MS Rep. Fish. Aquat. Sci. 1599: 72 p.

Ketchen, K. S., N. Bourne, and T. H. Butler. 1983. History and present status of fisheries for marine fishes and invertebrates in the Strait of Georgia, British Columbia. Can. J. Fish. Aquat. Sci. 40: 1095-1119.

Ketchen, K. S. and C. R. Forrester. 1966. Population dynamics of the petrale sole, *Eopsetta jordani*, in waters off western Canada. Fish. Res. Board Can. Bull. 153.

Ketchen, K. S., B. M. Leaman, S. J. Westrheim, and C. C. Wood. 1978. Total allowable catches for 1978 for stocks of rockfish, blackcod and dogfish in waters off the west coast of Canada. Sci. Adv. Comm. Rep., Dept. Fish. and Environ. 89 p.

Kieser, R. 1983. Hydroacoustic biomass estimates of bathypelagic groundfish in Georgia Strait, January, February, and April, 1981. Can. MS Rep. Fish. Aquat. Sci. 1715: 84 p.

Kimura, D. K. 1981. Standardized measures of relative abundance based on modelling log (CPUE), and their application to Pacific ocean perch (*Sebastes alutus*). J. Cons. Int. Explor. Mer. 39: 211-218.

Kimura, D. K. In prep. Variability in estimating catch-in-numbers-at-age and its impact on cohort analysis. Unpubl. manuscr. 32 p. Northwest and Alaska Fisheries Center, Natnl. Mar. Fish. Ser., Bldg. 4 BIN C15700, 7600 Sand Point Way NE, Seattle, WA 98115-6349. Contribution prepared for the INPFC meeting Oct. 1987, Vancouver, B.C., Canada.

Kimura, D. K., J. W. Balsiger, and D. H. Ito. 1984. Generalized stock reduction analysis. Can. J. Fish. Aquat. Sci. 41: 1325-1333.

Lapi, L. A. and J. E. Richards. 1981. Data collected during rockfish (*Sebastes* spp.) assessments of the west Langara Is. and west coast Vancouver Is. fishing grounds in 1979. Can. Data Rep. Fish. Aquat. Sci. 286: 113 p.

Leaman, B. M. 1981. A brief review of survey methodology with regard to groundfish stock assessment. *In*: Doubleday, W. G. and D. Rivard (eds.). Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58: 113-123.

Leaman, B. M. 1985. Slope rockfish. *In*: Tyler, A. V. and G. A. McFarlane (eds.). Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 247-342.

Leaman, B. M. 1987a. Incorporating reproductive value into Pacific ocean perch management. pp. 355-368. *In*: Proceedings of the International Rockfish Symposium. Univ. of Alaska Sea Grant Rep. 87-2.

Leaman, B. M. 1987b. Slope rockfish. In: Tyler, A. V. and M. Saunders (eds.). Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 105-140.

Leaman, B. M., D. Davenport, W. R. Harling, D. A. Nagtegaal, W. R. Ostermann, J. R. Selsby, and G. A. Thomas. 1978. Biological observer coverage of foreign fisheries off Canada's Pacific coast, 1977. Fish. Mar. Serv. Data Rep. 99. Pts. I-IV: 598 p.

Leaman, B. M., G. E. Gillespie, D. A. Nagtegaal, and R. D. Stanley. 1987. Biomass survey of rockfish stocks off the southwest coast of Vancouver Island, September 8-22, 1985 (M/V HOWE BAY). Can. Tech. Rep. Fish. Aquat. Sci. (in press).

Leaman, B. M. and D. A. Nagtegaal. 1982. Biomass estimation of rockfish stocks off the west coast off the Queen Charlotte Islands during 1978 and 1979. Can. MS Rep. Fish. Aquat. Sci. 1652: 46 p.

Leaman, B. M. and D. A. Nagtegaal. 1986. Biomass survey of rockfish stocks in the Dixon Entrance-Southeast Alaska region, July 5-22, 1983 (R/V G.B. REED and M/V FREE ENTERPRISE No. 1). Can. Tech. Rep. Fish. Aquat. Sci. 1510: 63 p.

Leaman, B. M. and D. A. Nagtegaal. 1987. Identification of species assemblages and results of management applications for shelf and slope rockfishes off British Columbia. pp. 309-328. In: Proceedings of the International Rockfish Symposium. Univ. of Alaska Sea Grant Rep. 87-2.

Leaman, B. M. and R. D. Stanley. 1985. Shelf and slope rockfishes. In: A. V. Tyler, and G. A. McFarlane [eds.]. 1985. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS. Rep. Fish. Aquat. Sci. No. 1813: 247-249.

Leaman, B. M. and R. D. Stanley. 1987. From nobility to nightmares: some object lessons in the planning and conduct of fishery harvest experiments. Ms. presented at the 1987 Western Groundfish Conference, Gleneden, Oregon.

Leaman, J. E. 1982. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1124: 90 p.

Leaman, J. E. 1983. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1982. Can. Tech. Rep. Fish. Aquat. Sci. 1226: 88 p.

Leslie, P. H. and D. H. S. Davis. 1939. An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8: 94-113.

Mangel, M. and J. H. Beder. 1985. Search and stock depletions: theory and applications. Can. J. Fish. Aquat. Sci. 42: 150-163.

Mathews, S. B. and M. W. Barker. 1983. Movements of rockfish (Sebastes) tagged in northern Puget Sound, Washington. Fish. Bull. 82: 916-922.

McElderry, H. I. and L. J. Richards. 1984. Recreational SCUBA diving in the Strait of Georgia: An analysis of the distribution of diving effort and the importance of collecting marine animals. Can. MS Rep. Fish. Aquat. Sci. 1794: 61 p.

McFarlane, G. A. and R. C. Francis. 1985. Pacific hake: West coast of Vancouver Island. In: Tyler, A. V. and G. A. McFarlane [eds.]. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 163-186.

McFarlane, G. A., W. Shaw, and R. J. Beamish. 1983. Observations on the biology and distribution of Pacific hake, walleye pollock and spiny dogfish in the Strait of Georgia--February 20-May 2, and July 3, 1981. Can. MS Rep. Fish. Aquat. Sci. 1722: 109 p.

McFarlane, G. A., W. Shaw, and A. V. Tyler. 1985. Sablefish. In Tyler, A. V. and G. A. McFarlane [eds.]. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 163-186.

Nagtegaal, D. A. and S. P. Farlinger. 1980. Catches and trawl locations of M/V BLUE WATERS during rockfish exploration and assessment cruise to the west coast of the Queen Charlotte Islands, 1979. Can. Data Rep. Fish. Aquat. Sci. 215: 74 p.

Nagtegaal, D. N., B. M. Leaman, and R. D. Stanley. 1986. Catches and trawl locations of R/V G.B. REED and M/V EASTWARD HO during the Pacific ocean perch assessment cruise to Queen Charlotte Sound, August-September, 1984. Can. Data Rep. Fish. Aquat. Sci. 611: 109 p.

Nagtegaal, D. A., G. A. Thomas, and B. M. Leaman. 1980. Catches and trawl locations of M/V BLUE WATERS during rockfish exploration and assessment cruises to the west coast of the Queen Charlotte Islands and the northwest coast of Vancouver Island in 1978. Can. Data Rep. Fish. Aquat. Sci. 218: 103 p.

Paloheimo, J. E. 1980. Estimation of mortality rates in fish populations. Trans. Amer. Fish. Soc. 109: 378-386.

Pedersen, M. G. 1975. Recent investigations of petrale sole off Washington and British Columbia. Wash. Dept. Fish. Tech. Rep. 17: 72 p.

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Int. Comm. for the Northwest Atlantic Fisheries Bulletin 9: 65-74.

Richards, L. J. 1986. PSARC working paper G86-1. 1986 assessment for commercially exploited rockfish stocks in the Strait of Georgia. Can. MS Rep. Fish. Aquat. Sci. 1885: 55 p.

Richards, L. J. and A. J. Cass. 1987. 1986 research catch and effort data on nearshore reef-fishes in British Columbia statistical areas 12, 13 and 16. Can. MS Rep. Fish. Aquat. Sci. 1903: 119 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191: 382 p.

Rivard, D. 1982. APL programs for stock assessment (revised). Can. Tech. Rep. Fish. Aquat. Sci. 1091: 146 p.

Saunders, M. W. 1985. Dogfish. In Tyler, A. V. and G. A. McFarlane [eds.]. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 11-226.

Saunders, M. W. 1986. Dogfish. In Tyler, A. V., R. P. Foucher, and J. Fargo [eds.]. 1986. Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986. Can. MS Rep. Fish. Aquat. Sci. 1897: 108 p.

Saunders, M. W. 1987. Dogfish. In Tyler, A. V. and M. W. Saunders [eds]. 1987. Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 156 p.

Saunders, M. W., G. A. McFarlane, and W. Shaw. 1987. Sablefish. In Tyler, A. V. and M. W. Saunders [eds.]. 1987. Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 156 p.

Schnute, J. 1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42: 414-429.

Schnute, J. 1987. A general fishery model for a size-structured fish population. Can. J. Fish. Aquat. Sci. 44: 924-940.

Schnute, J. and D. A. Fournier. 1980. A new approach to length frequency analysis: growth structure. J. Fish. Res. Board Can. 37: 1337-1351.

Shaw, W. and C. P. Archibald. 1981. Length and age data of rockfishes collected from B.C. coastal waters during 1977, 1978, and 1979. Can. Data Rep. Fish. Aquat. Sci. 289: 119 p.

Shaw, W., G. A. McFarlane, and M. W. Saunders. 1985. Walleye pollock. In Tyler, A. V. and G. A. McFarlane [eds.]. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 227-246.

Shuter, B. J. and J. F. Koonce. 1985. A review of methods for setting catch quotas on fish stocks. Unpubl. manuscr., 78 p. Research Section, Fisheries Branch, Ontario Ministry of Natural Resources, P. O. Box 50, Maple, Ontario, L0J 1E0. (Contribution to Assessment of Stocks and Prediction of Yield workshop, Thunder Bay, Ontario, Canada, August 1985.)

Smith, J. E. 1980. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1979. Can. Tech. Rep. Fish. Aquat. Sci. 961: 90 p.

Smith, J. E. 1981. Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1032: 90 p.

Stanley, R. 1985. Shelf rockfishes (silvergray, yellowtail, canary rockfish). In: A. V. Tyler, and G. A. McFarlane [eds.]. 1985. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. No. 1813: 308-342.

Stanley, R. D. 1987a. Shelf Rockfish (silvergray, yellowtail, canary rockfish). In: A. V. Tyler, and M. W. Saunders. [Eds.]. Groundfish stock assessments for the west coast of Canada in 1986 and recommended yield options for 1987. Can. MS Rep. Fish. Aquat. Sci. 1930: 156 p.

Stanley, R. D. 1987b. Use of a length frequency simulator to explore the information content in length data for a long-lived species, silvergray rockfish (Sebastes brevispinis). pp. 155-170. In: Proceedings of the International Rockfish Symposium. Univ. of Alaska Sea Grant Rep. 87-2: 155-170.

Stanley, R. D. (In prep.) Assessment and sampling implications of the variance in LPUE estimates for seven Pacific coast groundfish fisheries. Can. J. Fish. Aquat. Sci.

Stocker, M. Editor. 1981. Groundfish stock assessments off the west coast of Canada in 1981 and recommended total allowable catches for 1982. Can. MS Rep. Fish. Aquat. Sci. 1626: 282 p.

Swartzman, G. L., W. M. Getz, R. C. Francis, R. T. Haar, and K. Rose. 1983. A management analysis of the Pacific whiting (Merluccius productus) fishery using an age-structured stochastic recruitment model. Can. J. Fish. Aquat. Sci. 40: 524-539.

Tagart, J. V. 1985. Status of the yellowtail rockfish stocks in the International North Pacific Fishery Commission Vancouver and Columbia areas in 1985. Manuscript Report, WDF, Appendix 6 of "Status of Pacific Coast Groundfish Fishery and Recommendations for Management in 1986". Pacific Fishery Management Council, 26 SW. Mill Street, Portland, Oregon 97201.

Tagart, J. V. and D. K. Kimura. 1982. Review of Washington's Coastal Trawl Rockfish Fishery. Wash. Dept. Fish. Tech. Rep. No. 68: 66 p.

Thompson, J. M. and G. A. McFarlane. 1982. Distribution and abundance of Pacific hake and walleye pollock in the Strait of Georgia, March 24-May 2 1981. Can. MS Rep. Fish. Aquat. Sci. 1661: 79 p.

Tomlinson, P. K. 1970. A generalization of the Murphy catch equation. J. Fish. Res. Board Can. 27: 821-825.

Tyler, A. V. 1982. User manual for RECON: A general fish-stock reconstruction model at Oregon State University. O.S.U. Sea Grant Publication #ORESU-H1-83-003. pp. 1-20.

Walters, C. J. 1969. A generalized computer simulation model for fish population studies. Trans. Amer. Fish. Soc. Vol. 98: 505-512.

Walters, C. J. 1986a. Derivation of a general depletion estimation procedure. MS. Univ. of Brit. Col.

Walters, C. J. 1986b. MS. Microcomputer catch at age analysis system. User's manual. 52 p.

Wendler, H. O. 1953. Length-weight relationships of the lingcod. Wash. Dept. Fish. Res. Pap. 1: 25-32.

Westrheim, S. J. 1975. Reproduction, maturation, identification of larvae of some _Sebastes_ (Scorpaenidae) species in the Northeast Pacific Ocean. J. Fish. Res. Board Can. 32(12): 2399-2411.

Westrheim, S. J. 1983. A new method for allotting effort to individual species in a mixed-species trawl fishery. Can. J. Fish. Aquat. Sci. 40: 352-360.

Westrheim, S. J., J. Fargo, and R. P. Foucher (In prep.) Stock assessments of individual species in a mixed-species trawl fishery: some hazards.

Westrheim, S. J. and R. P. Foucher. 1985a. Pacific cod. _In_: Tyler, A. V. and G. A. McFarlane [eds.]. 1985. Groundfish stock assessments for the west coast of Canada in 1984, and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813: 353 p.

Westrheim, S. J. and R. P. Foucher. 1985b. Relative fishing power for Canadian trawlers landing Pacific cod (_Gadus macrocephalus_) and important shelf cohabitants from major offshore areas of Western Canada, 1960-81. Can. J. Fish. Aquat. Sci. 42: 1614-1626.

Westrheim, S. J. and R. P. Foucher. 1987. Stock assessment of Pacific cod (_Gadus macrocephalus_) in Georgia and Juan de Fuca Straits, 1954-84. Can. MS Rep. Fish. Aquat. Sci. 1905: 84 p.

Westrheim, S. J., D. R. Gunderson, and J. M. Meehan. 1972. On the status of Pacific ocean perch (_Sebastes alutus_) stocks off British Columbia, Washington, and Oregon in 1970. Fish. Res. Board Can. Tech. Rep. 326: 48 p.

Wood, C. C., K. S. Ketchen, and R. J. Beamish. 1979. Population dynamics of spiny dogfish (_Squalus acanthias_) in British Columbia waters. J. Fish. Res. Board Can. 36: 647-656.